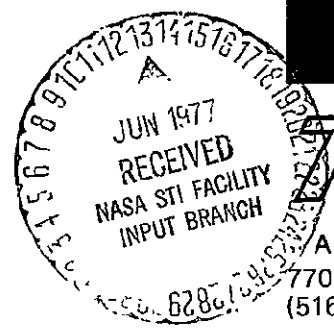
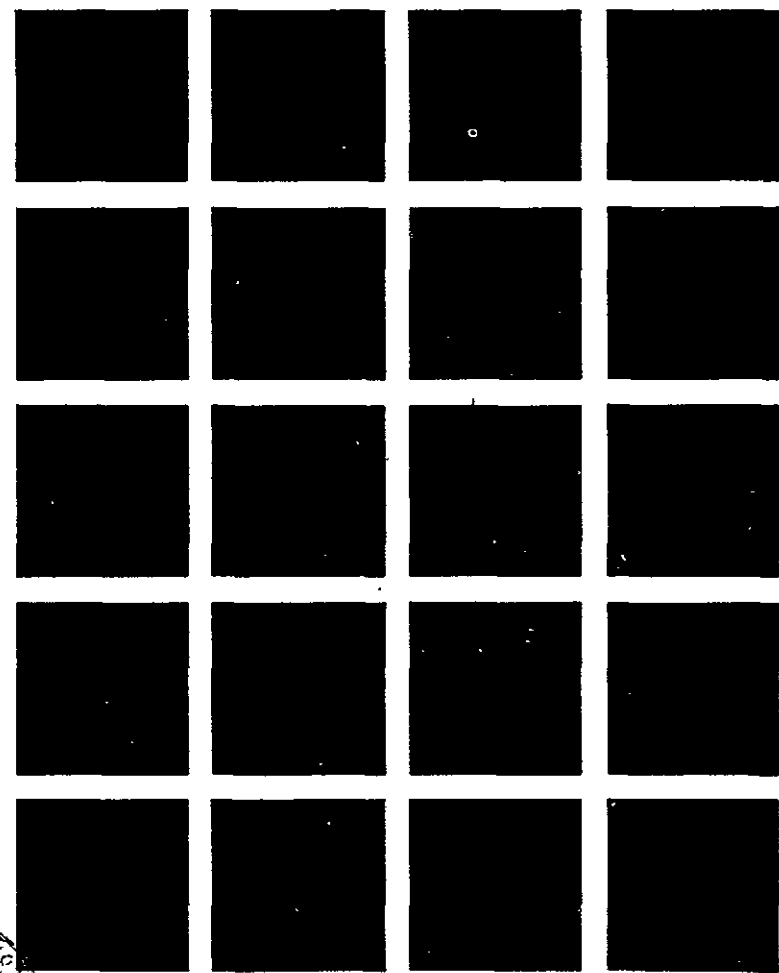


CR 151265

N77-24769

(NASA-CR-151265) EVALUATION OF LIGHTWEIGHT
HEADSETS FOR SPACE SHUTTLE APPLICATION
Final Technical Report (Telephonics,
Huntington, N.Y.) 75 p HC A04/MF A01
CSCL 05H G3/54

Unclass
30319



Telephonics

A DIVISION OF INSTRUMENT SYSTEMS CORPORATION
770 PARK AVENUE, HUNTINGTON, NEW YORK 11743
(516) 549-6000 TWX: 510-226-6983 Cable: INSSYSTHTGN

FINAL TECHNICAL REPORT

EVALUATION OF LIGHTWEIGHT
HEADSETS FOR SPACE SHUTTLE
APPLICATION

CONTRACT # NAS-9-14824

DATA ITEM - MA-129T

OCTOBER, 1976

TELEPHONICS CORPORATION
770 PARK AVE.
HUNTINGTON, NEW YORK

Telephonics

A DIVISION OF INSTRUMENT SYSTEMS CORPORATION

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ABSTRACT

The objectives of this study were to obtain contemporary lightweight headsets currently being manufactured and evaluate them for:

- o Intelligibility
- o Frequency Response
- o Sensitivity
- o Distortion
- o Noise Isolation
- o Acoustic Quality
- o Weight
- o Wearer Confort

Thirty two letters, a sample of which is in Appendix A, were sent to manufacturers (See Appendix B) of commercial and military headsets. Five of the manufacturers responded affirmatively with a total of eight headsets for evaluation.

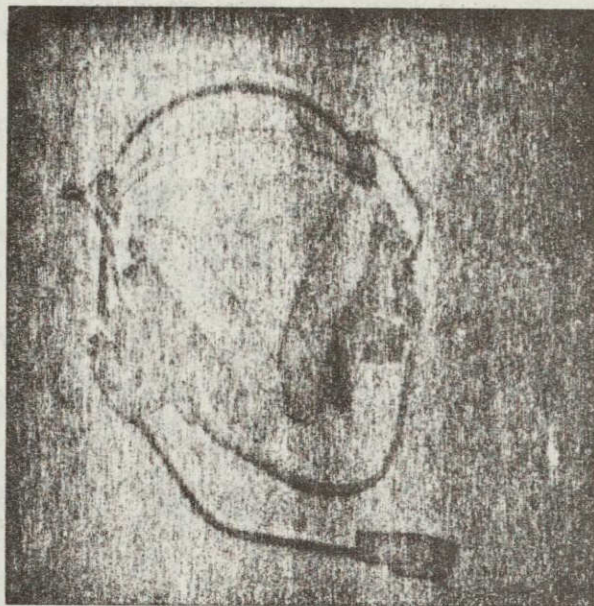
Each headset was rank ordered for the catagories where statistically significant numbers were obtained. Subjective comments were good, fair, or poor when applied to human factors critiques.

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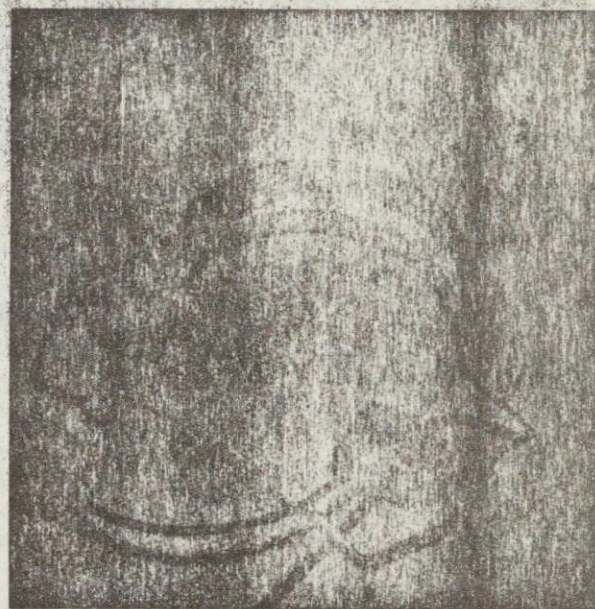
I.

Pictorial Description of Headsets



Manufacturer: Avid
Model #: LT-730
Microphone: Dynamic, first
order Gradient
Earphone: Circumaural,
dynamic

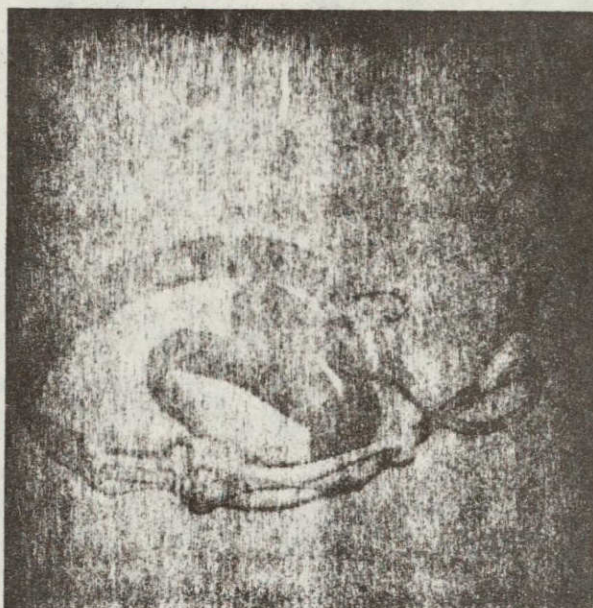
Manufacturer: Telex
Model #: 5x5
Microphone: Electret, First Order
Gradient
Earphone: Ear Insert, Magnetic



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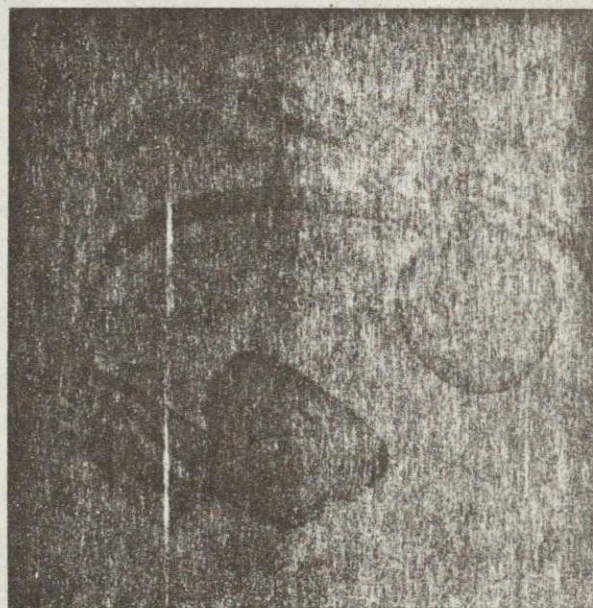
A DIVISION OF INSTRUMENT SYSTEMS CORPORATION

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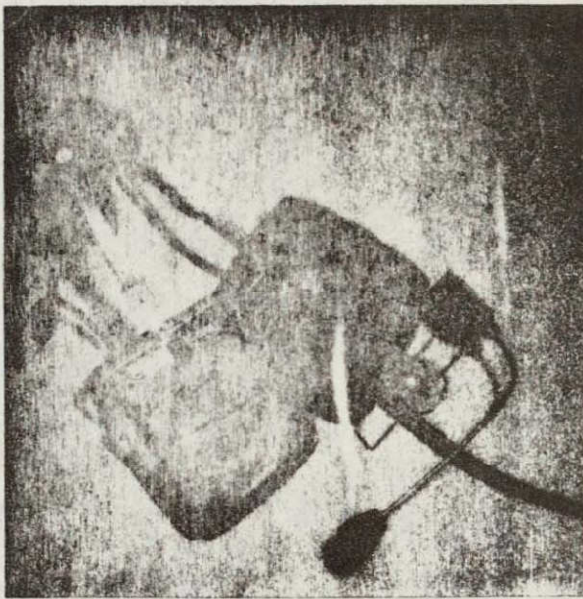
Manufacturer: Sennheiser
Model #: HMD 110
Microphone: Dynamic, super
cardiod
Earphone: Circumaural, dynamic

Manufacturer: Telex
Model #: TAH-29
Earphone: Supraaural, dynamic



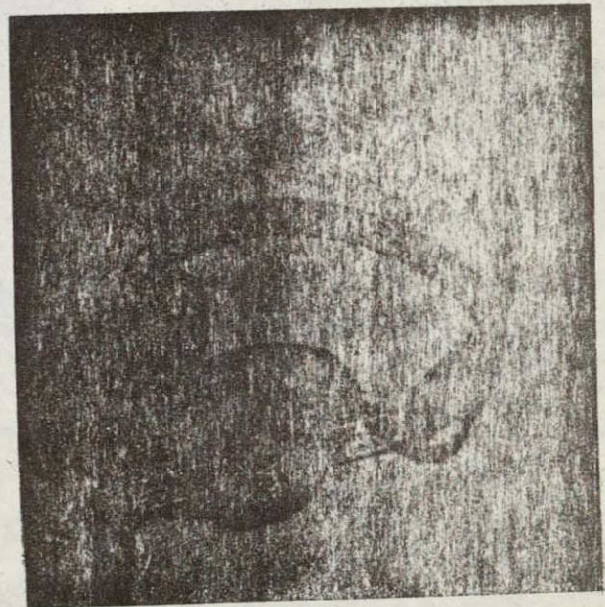
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Manufacturer: Roanwell
Model #: 125610
Microphone: Magnetic, first
order gradient
Earphone: Magnetic, Circu-
maural

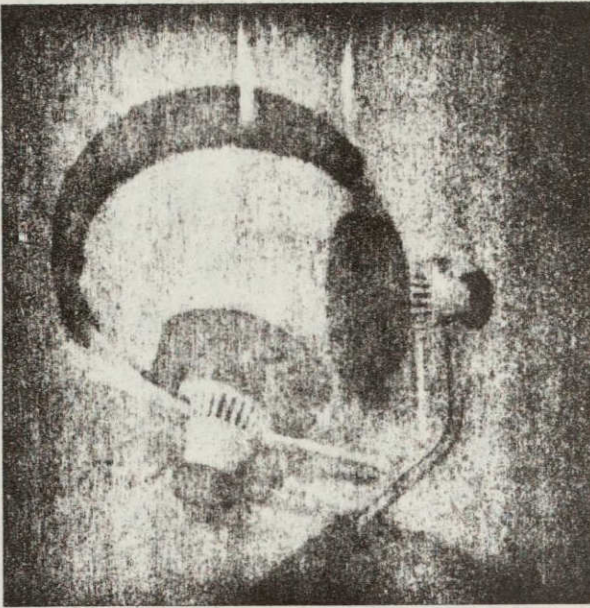
Manufacturer: Telex
Model #: A610
Earphone: Circumanural,
magnetic



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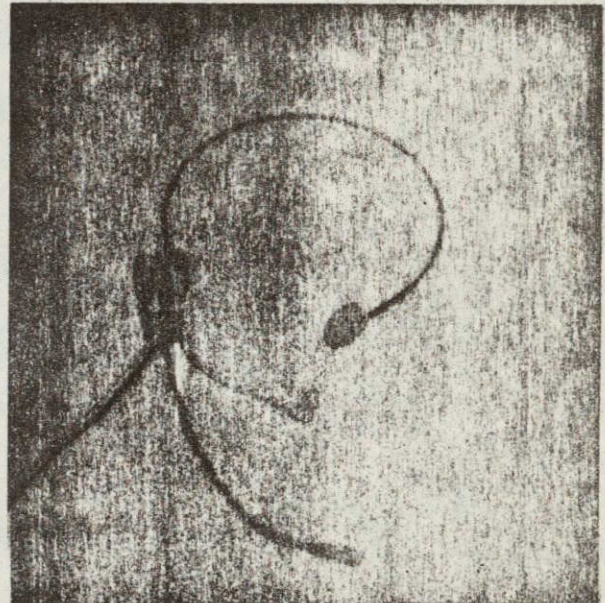
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Manufacturer: Sennheiser
Model #: HMD 414
Microphone: Dynamic, super
cardiod
Earphone: Supraaural, dynamic

Manufacturer: Unex
Model #: HS-2A
Earphone: Single ear insert,
magnetic
Microphone: Electret, First
order gradient



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II. Description of Test Methods

1. Intelligibility Noise Test

A. Earphones

The method of measurement presented herein was the PB (phonetically balanced) monosyllabic word tests. The subjects listened in a quiet and in a noisy environment.

B. General

Five subjects were used in the testing. The listeners were seated in a semi reverberant room isolated from the talker. The talker used a B&K $\frac{1}{4}$ " condenser microphone with a foam breath shield. The talker held the breath shield to his or her's lips and simultaneously viewed a VU meter to insure uniform talker sensitivity for the duration of the testing. The listeners were allowed to adjust the volume level for each test until a comfortable level was achieved.

Each headset had 5 listening tests in quiet and 5 listening tests in 90 dB of white noise.

Actual measurements in the listening room were as listed in Table A.

TABLE A

<u>S.L.M. SETTING</u>	<u>QUIET AMBIENT</u> (DB)	<u>NOISE AMBIENT</u> (DB)
A Weighting	36	91
C Weighting	63	91
31.5 (HZ)	65	63
63	52	57
125	47	67
250	37	81
500	32	85
1000	22	84
2000	22	85
4000	22	86
8000	22	76
16000	24	65

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o Screening of Subject

The subjects were selected on the basis of a audiometric examination. (Audiograms are in Appendix C). The tests were performed by a certified audiometrist. The hearing loss of the selected subjects did not average more than 10dB.

The talkers and listeners had no speech defects or strong accents. The subjects were used no more than 1 hour each day to prevent inattentiveness and biased results which can accompany lengthy psychophysical testing.

o Training of Subjects

The subjects were trained by reading PB word lists to each other in quiet, face to face communication, without the use of headsets. These procedures were repeated until 96% or better scores were universally achieved.

The subjects were then trained using a B&K consenser microphone and a Koss ESP-9 electrostatic headset until the same scoring efficiency was achieved.

B. Microphones

The method of measurement used the same subjects and ambient as was used for the earphone testing.

The talker was seated in the semi reverberant room while the listener was isolated in another room. The listener used a pair of Koss ESP-9 electrostatic earphones and was allowed to adjust the level until comfortable.

The talker positioned the microphones $\frac{1}{4}$ inch from their lips and was presented with sidetone to the headset. Five tests were taken in quiet and in 90 dB of white noise.

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2. Frequency Response/Sensitivity

A. Microphone

A constant SPL of 94dB was used to excite the microphone under test. A B&K system illustrated in Appendix D was used to sweep the frequency and to record the microphone output. The sensitivity was recorded as E/P.

The microphones were measured under open circuit condition. The sensitivity in dB re 1V/N/m² and the E.O.L. rating are given on the response curves. The E.O.L. rating will give the sensitivity data in terms of power to allow comparison of the microphones with different impedances.

$$\text{E.O.L.} = 20 \log E - 10 \log R + 24$$

(Effective Output Level)

where E. = open circuit microphone output in volts when SPL is 10 dynes /cm² or 1 Newton/m² or 1 Pascal or 94dB SPL.

R = microphone impedance in ohms.

B. Earphone

A constant source of 1 milliwatt was fed to the earphone under test. A General Radio system illustrated in Appendix E was used to sweep the frequency and to record the earphones output.

A flat plate coupler using a B&K ½ inch microphone was used to couple the headset to the recording microphone. The earphone response curves shown in the DATA SECTION are not to be construed to represent how the ear senses the earphone output. There is, at present, no coupler that can claim recognition as a true "artificial ear" although some do approximate subjective data at the lower frequencies. The curves are taken so that an A/B type comparison can be made between earphones as to their general efficiency and frequency response.

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3. Distortion

Distortion measurements were made at 300, 1000, and 3000 HZ using the test set up described above with the addition of a Hewlett Packard model 333 distortion analyzer. The SPL was held at 100 dB at the microphone and from the earphone for the distortion measurements.

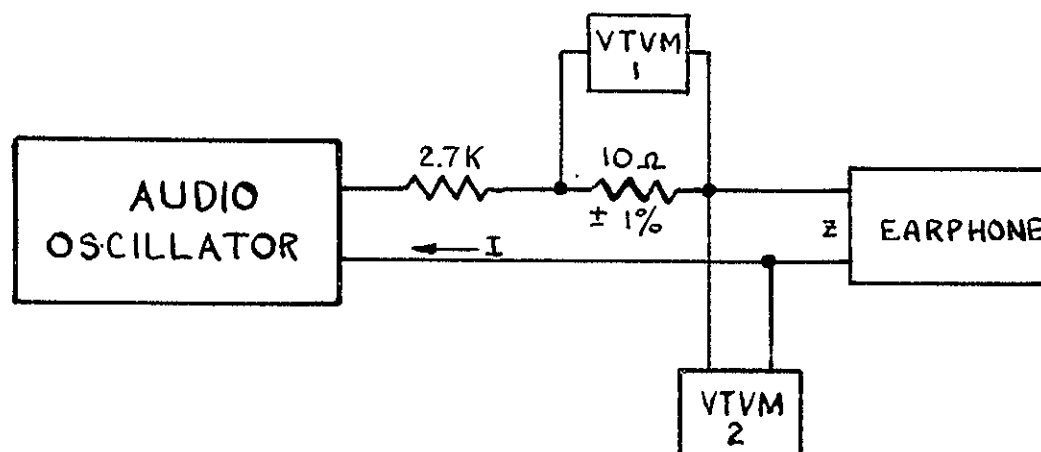
4. Impedance

The impedance of the microphone was measured using the 6dB down method i.e., The open circuit voltage was measured for a input SPL of 94 dB. The microphone output was then loaded with a precision variable resistor. The microphone impedance was taken as the reading variable resistor indicated when the initial microphone voltage measured was attenuated 6.0 dB.

The earphone impedance was measured using the dual volt-meter method. The current in the circuit below was measured using a precision 10 ohm resistor. The earphone impedance was then read directly on meter #2.

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$$I = \frac{V_1}{10}$$

$$Z = \frac{V_2}{I}$$

EARPHONE IMPEDANCE MEASUREMENT

III. Data Section

- A. Rank Order of Earphones for Intelligibility/ Noise Isolation. (The best intelligibility in noise condition this deemed the best noise isolation and is not to be construed as noise attenuation of the headset.)

		% INTELLIGIBILITY			
		<u>QUIET ($\bar{X}$)</u>	<u>σ</u>	<u>NOISE ($\bar{X}$)</u>	<u>σ</u>
1.	TAH-29	96.8%	3.03%	92.2%	3.76%
2.	125610	96	2.8	76.5	23.5
3.	HMD110	94	7.1	70.4	18.5
4.	5 x 5	95.6	4.6	60	21.5
5.	LT-730	96.5	1.0	51	25.4
6.	HS-2A	95.2	3.6	50	11.0
7.	HMD414	97.6	2.6	44.8	12.9
8.	A610	92	3.2	15.6	9.3

The statistical significance of the various measurements are shown in Appendix F together with the Raw Data.

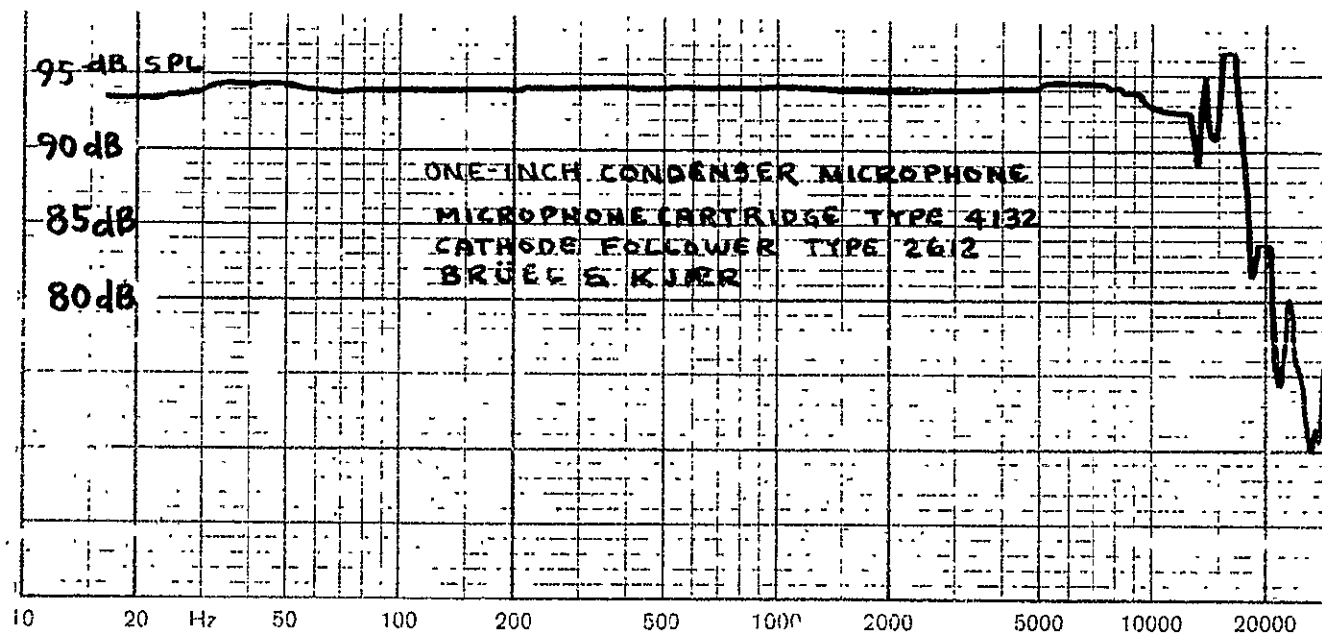
- B. Rank Order of Microphones for Intelligibility/ Noise Isolation

		% INTELLIGIBILITY			
		<u>QUIET ($\bar{X}$)</u>	<u>σ</u>	<u>NOISE ($\bar{X}$)</u>	<u>σ</u>
1.	HMD110	98.4%	1.67%	95.2%	2.68%
2.	5 x 5	98.0	2.45	94.0	3.16
3.	HMD414	98.8	1.8	87.2	9.9
4.	125610	97.6	2.2	82.4	16
5.	HS-2A	95.0	2.2	81.0	4.5
6.	LT-730	98.8	1.1	74.8	11

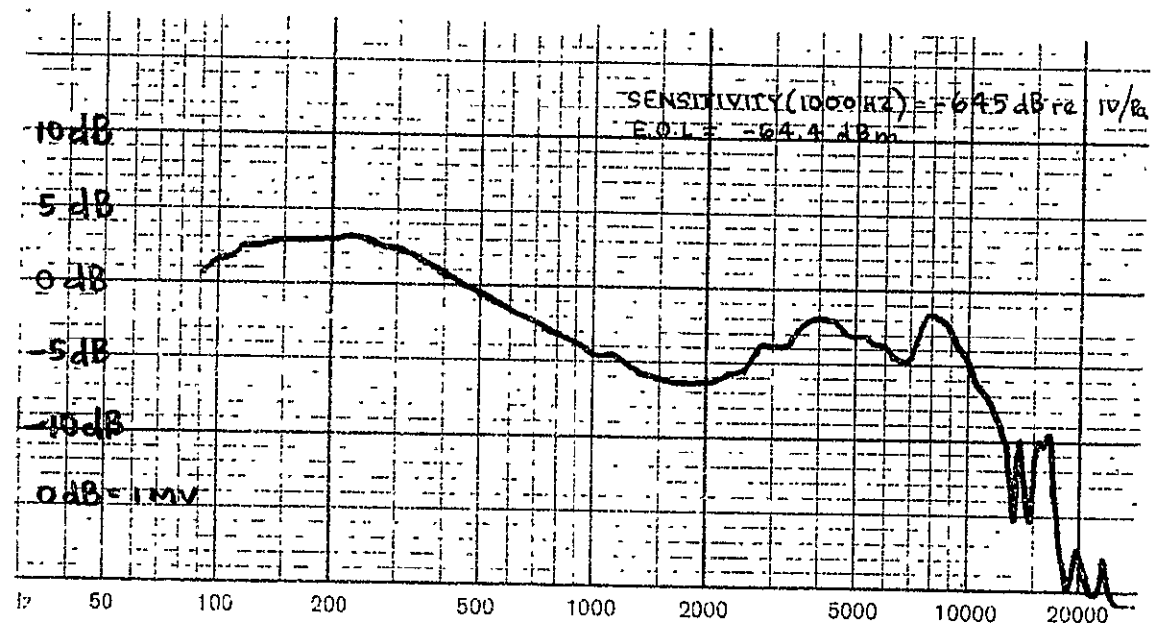
- C. Microphone Frequency Response and Sensitivity Figures.

Telephonics

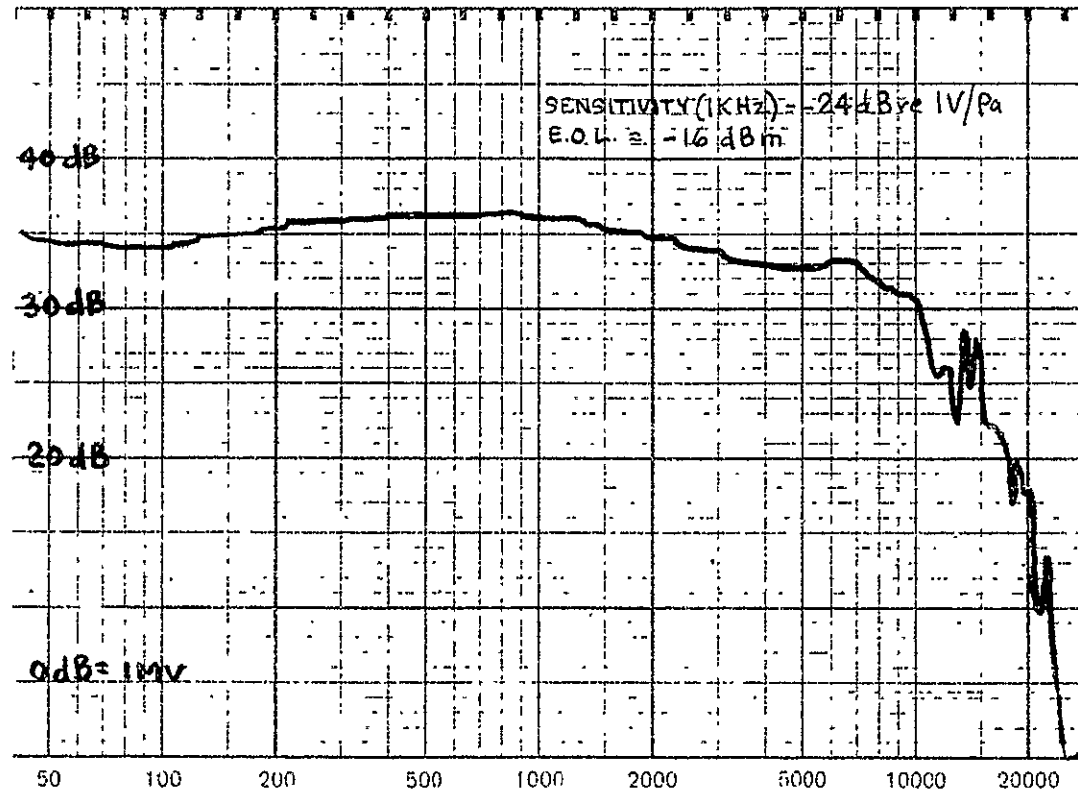
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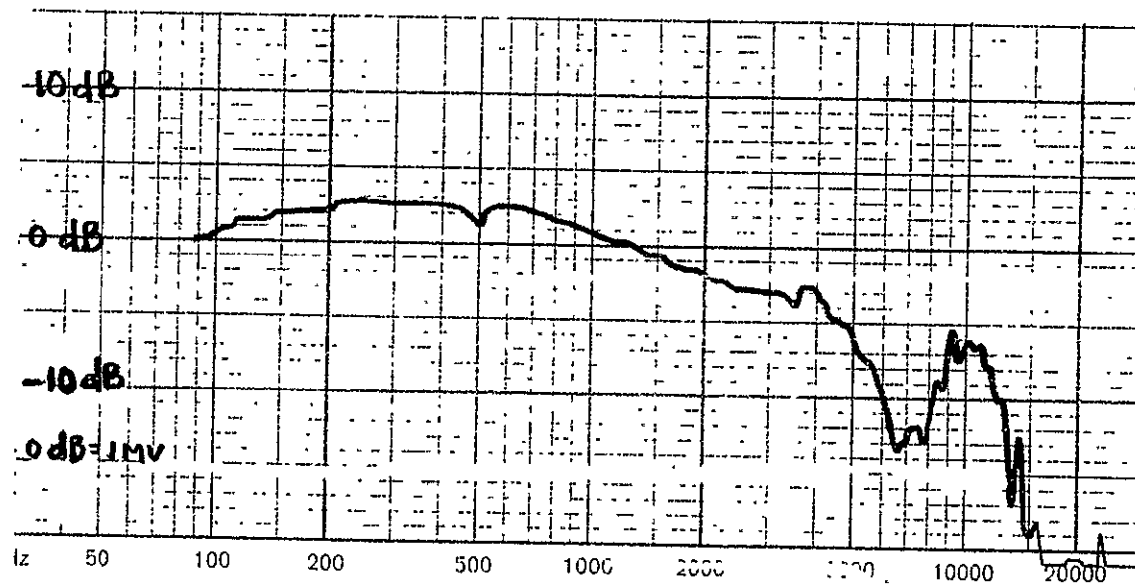
MICROPHONE CALIBRATION AND MEASURING SYSTEM RESPONSE



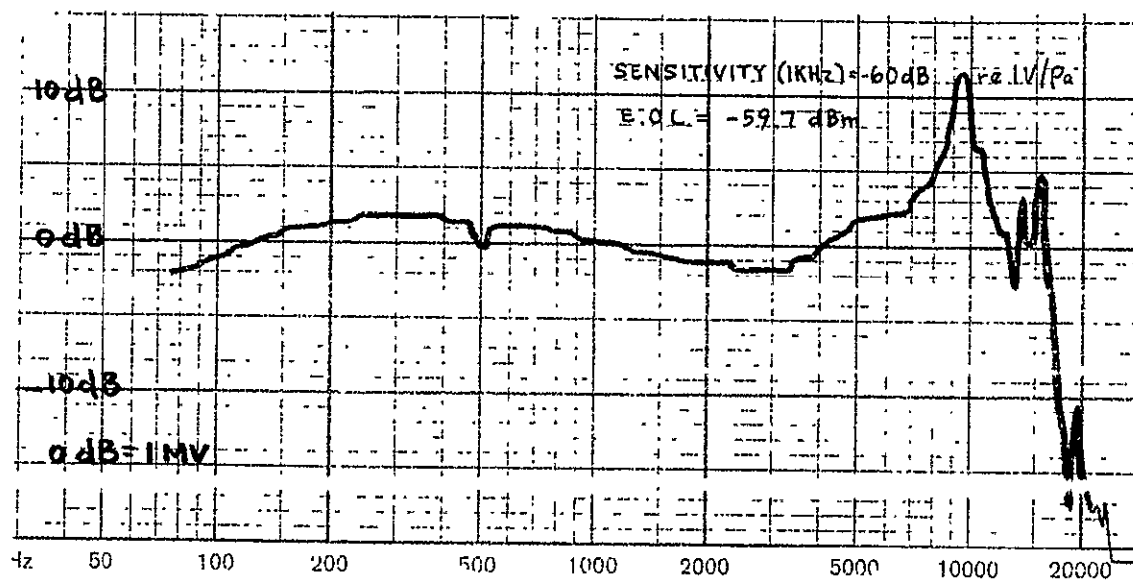
1. HMD110 MICROPHONE



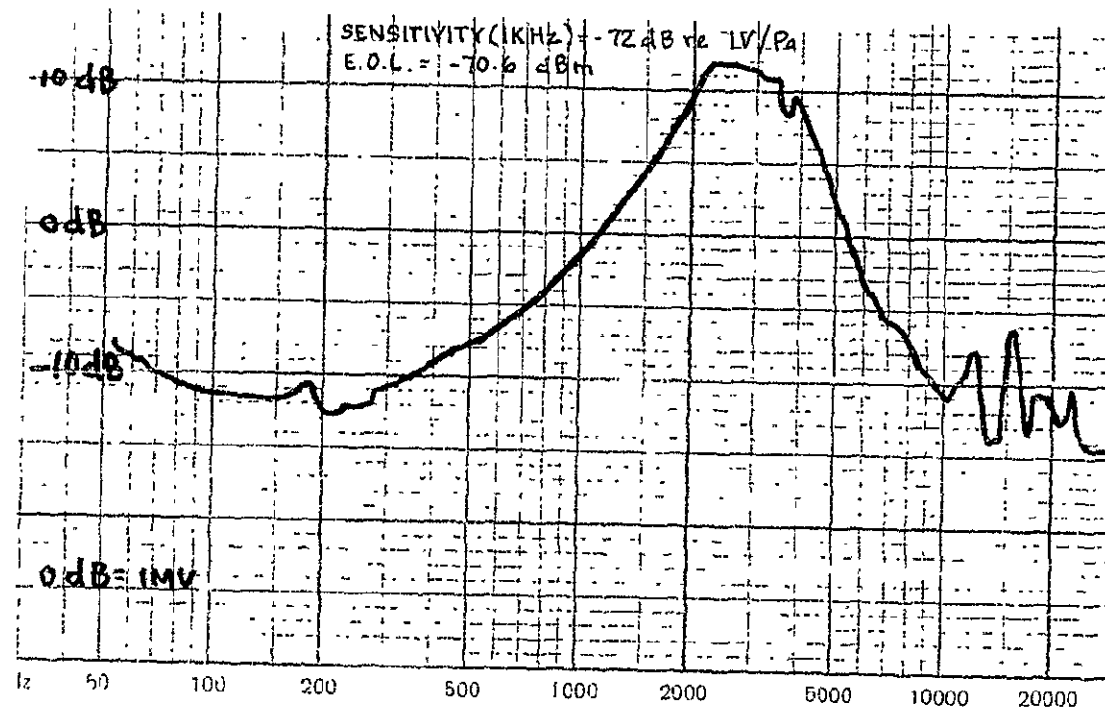
2. 5x5 MICROPHONE (AMPLIFIER IS ASSOCIATED WITH MICROPHONE)

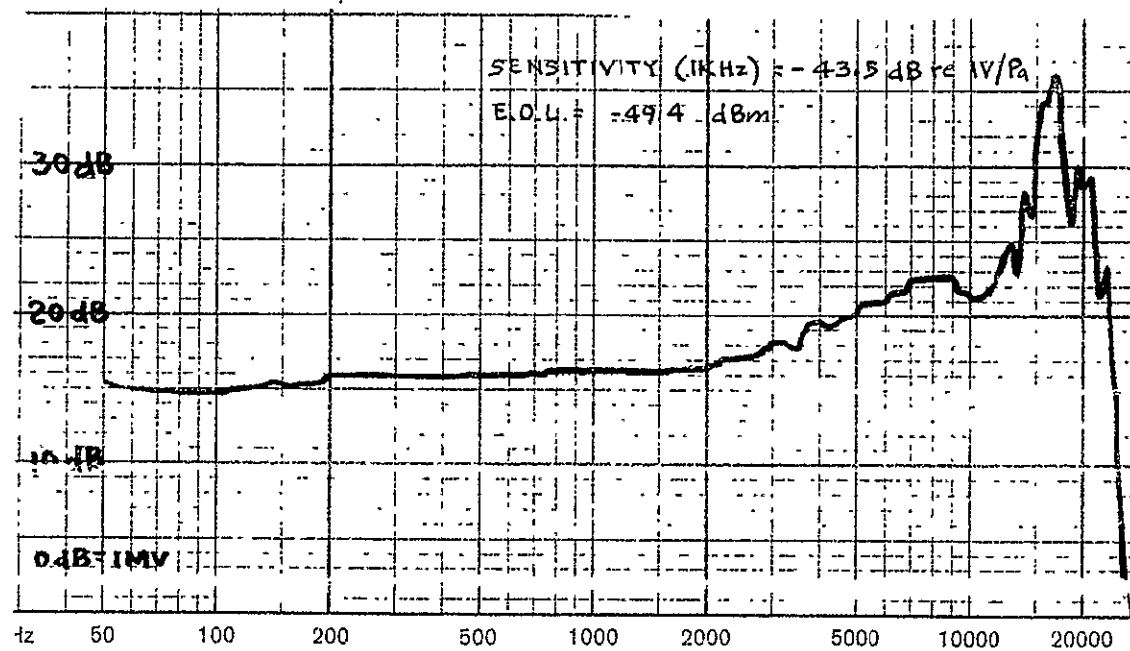


3a. HMD414 (SIDE FIRE)

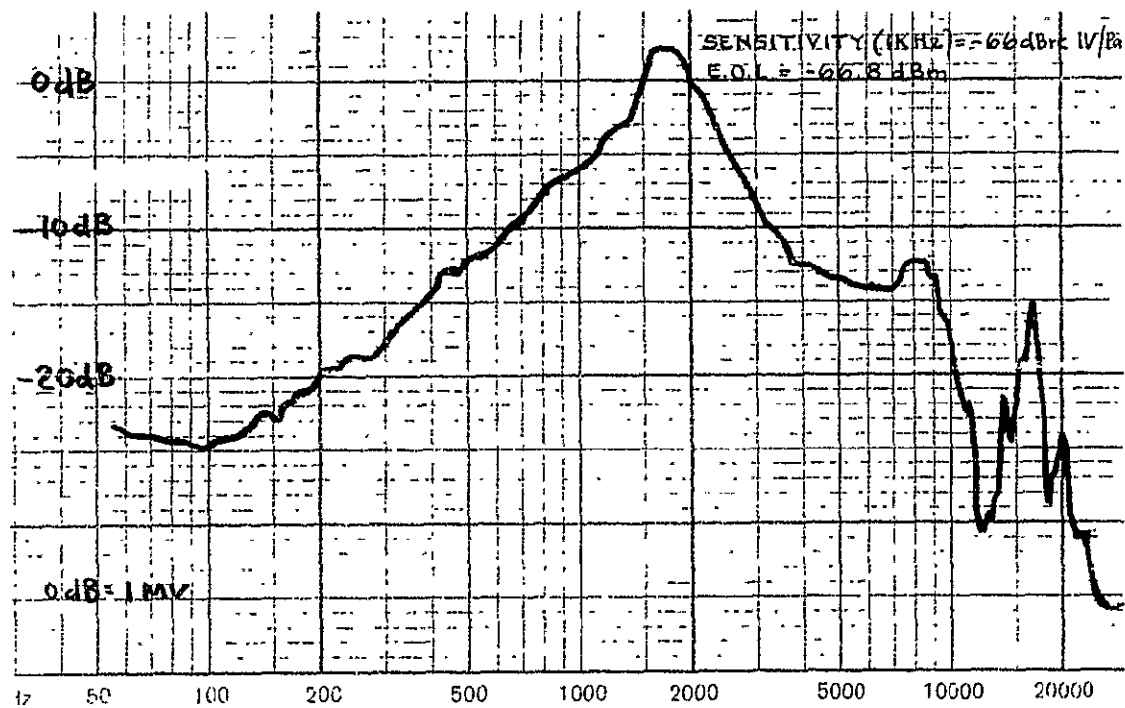


3. HMD414 MICROPHONE (END FIRE)





5. HS-2A MICROPHONE (1.5 VOLTS APPLIED TO AMPLIFIER)



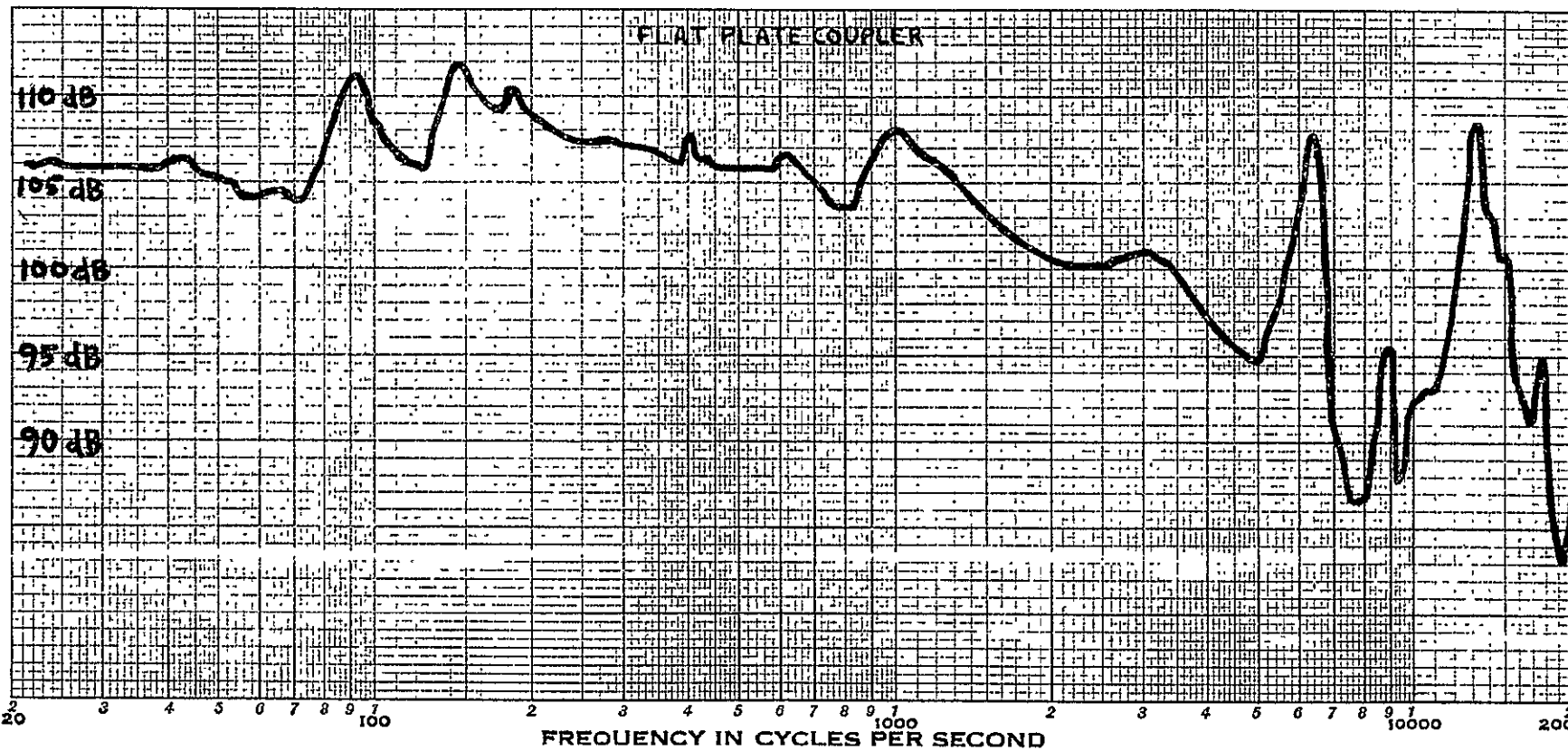
6. LT-730 MICROPHONE

D. Earphone Frequency Response and Sensitivity

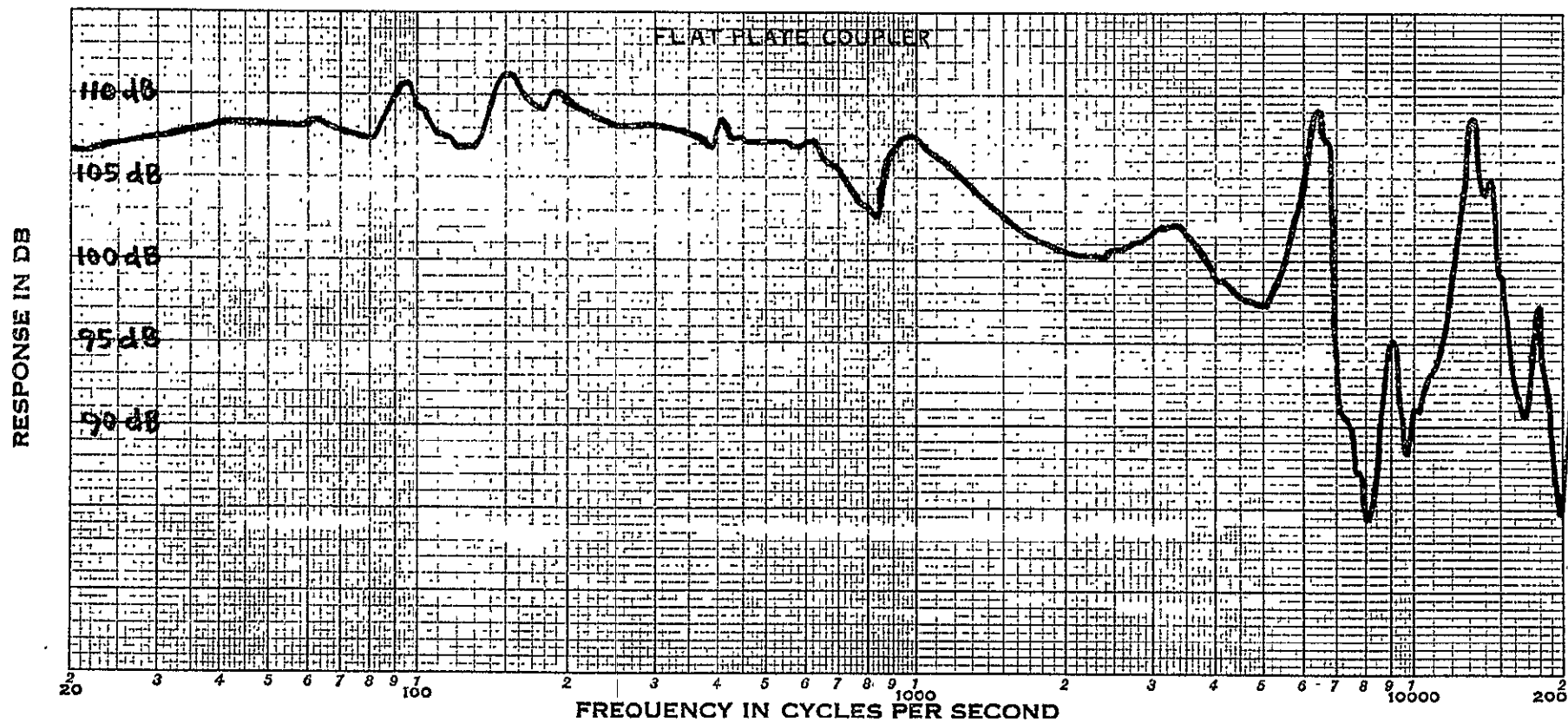
Telephonics

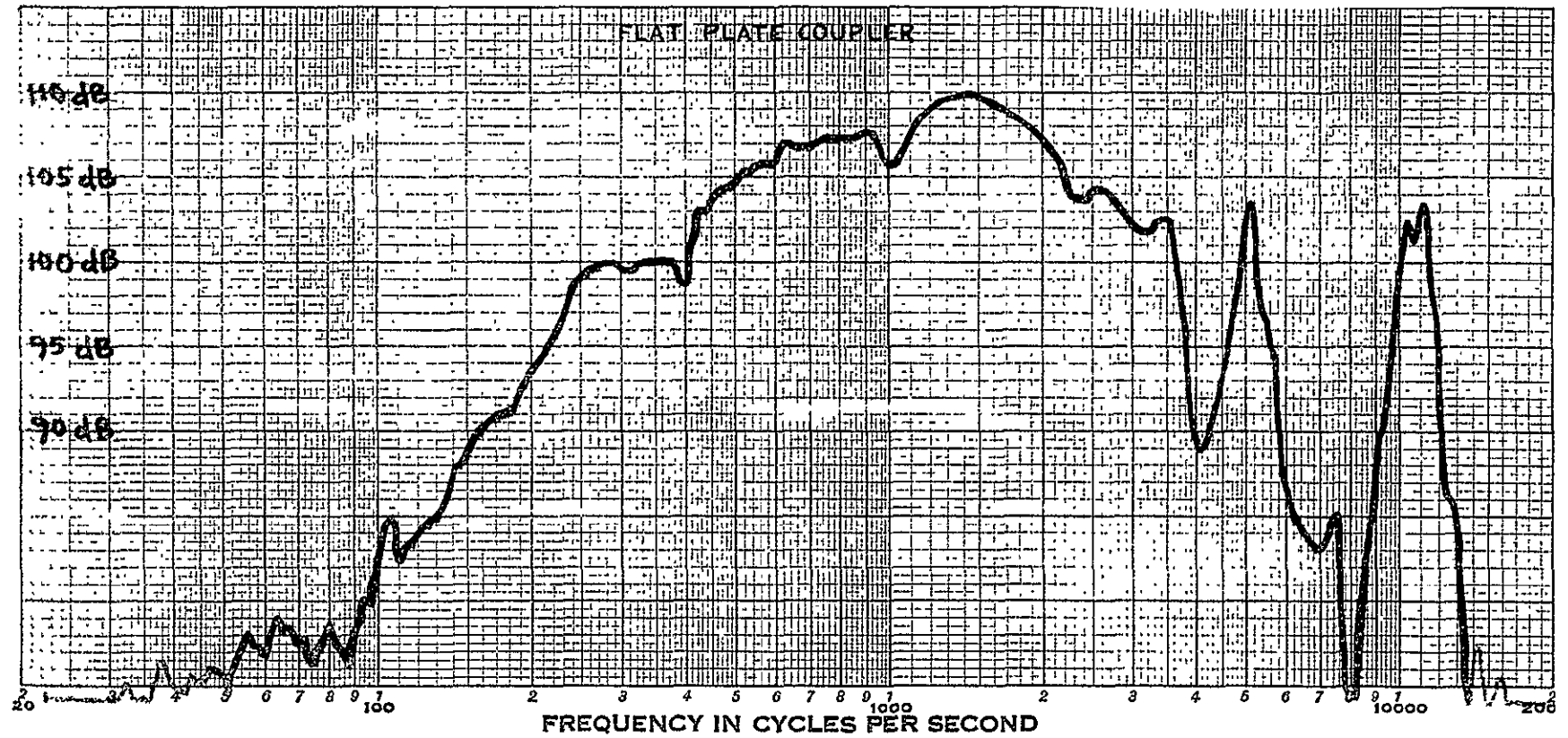
A DIVISION OF INSTRUMENT SYSTEMS CORPORATION

RESPONSE IN DB

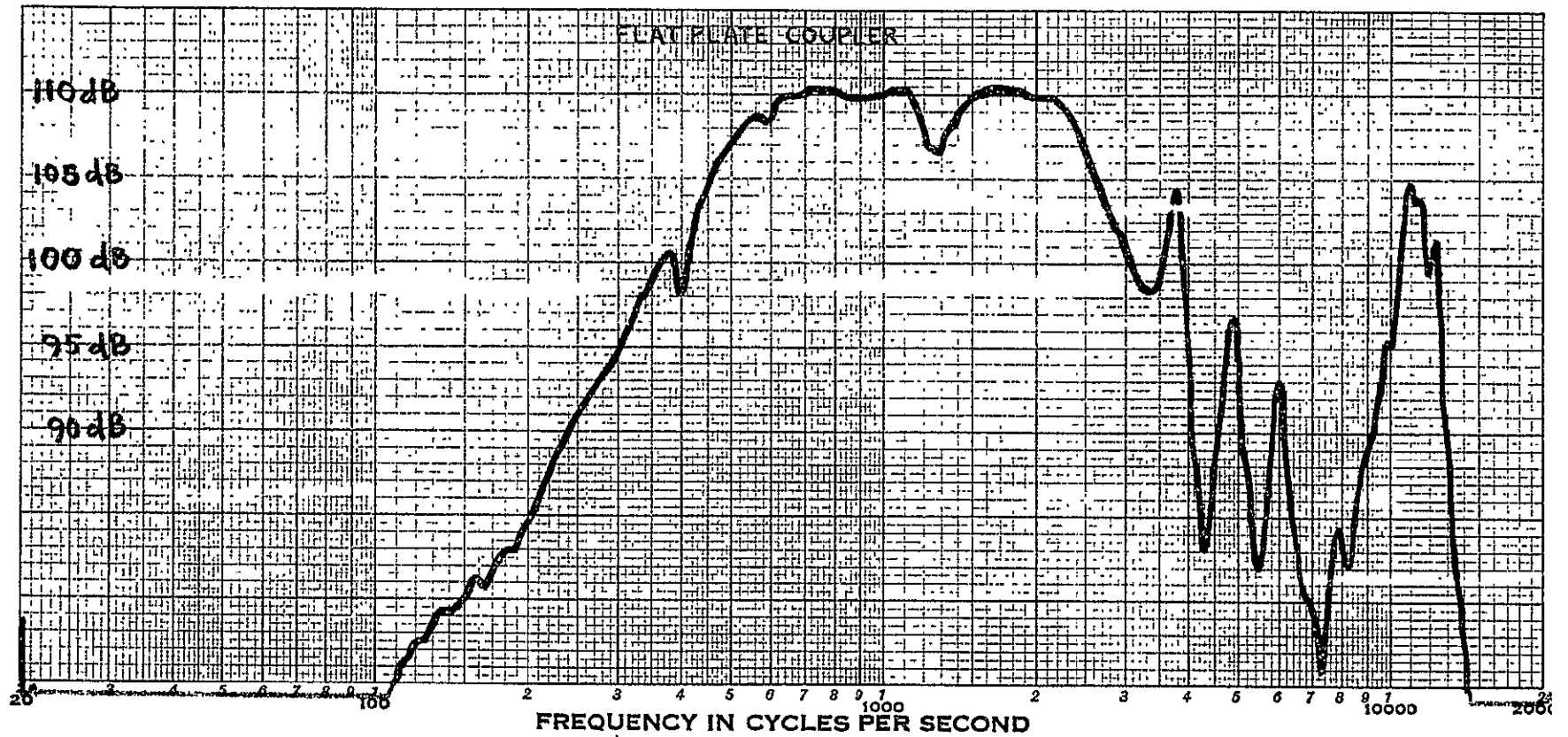


1a. TAH-29 EARPHONE (LEFT)

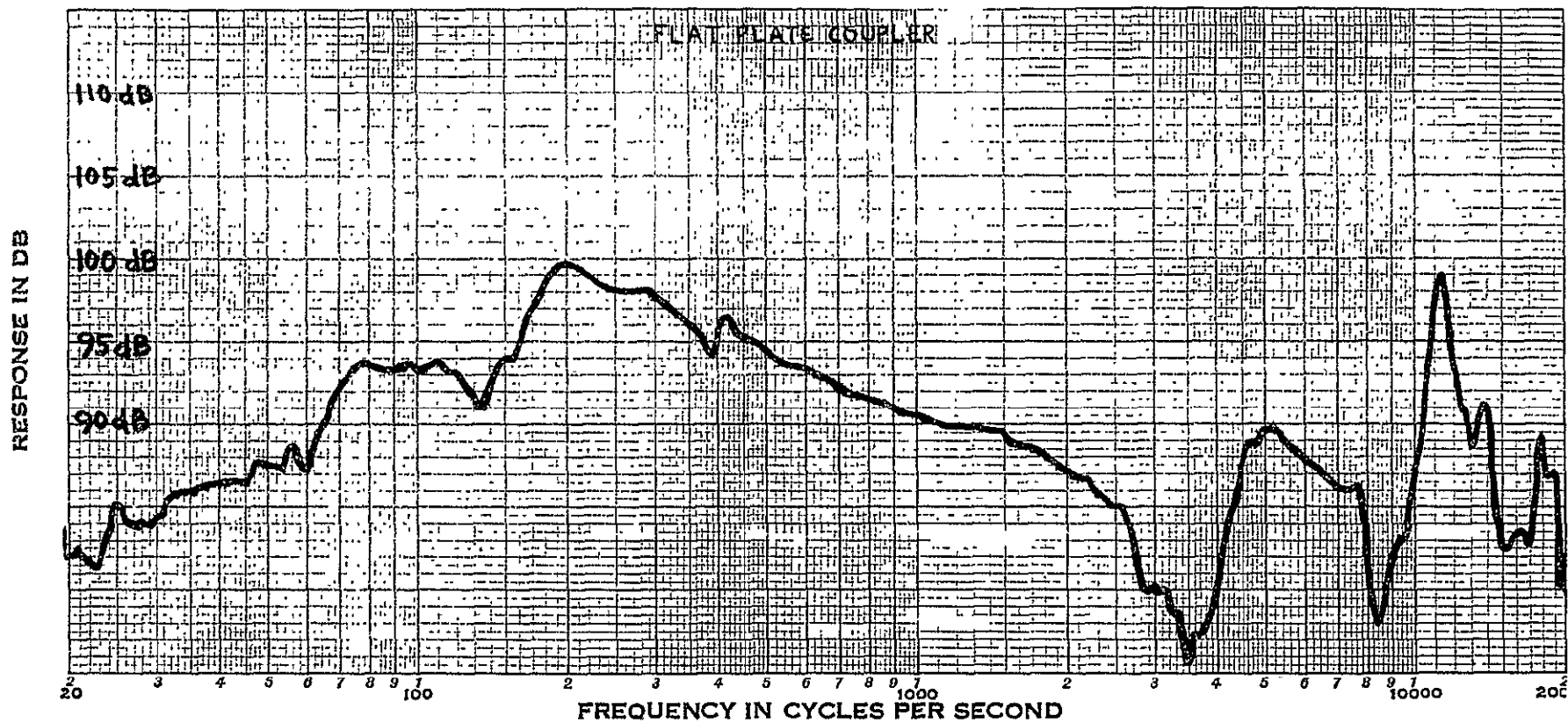




2a. RIGHT

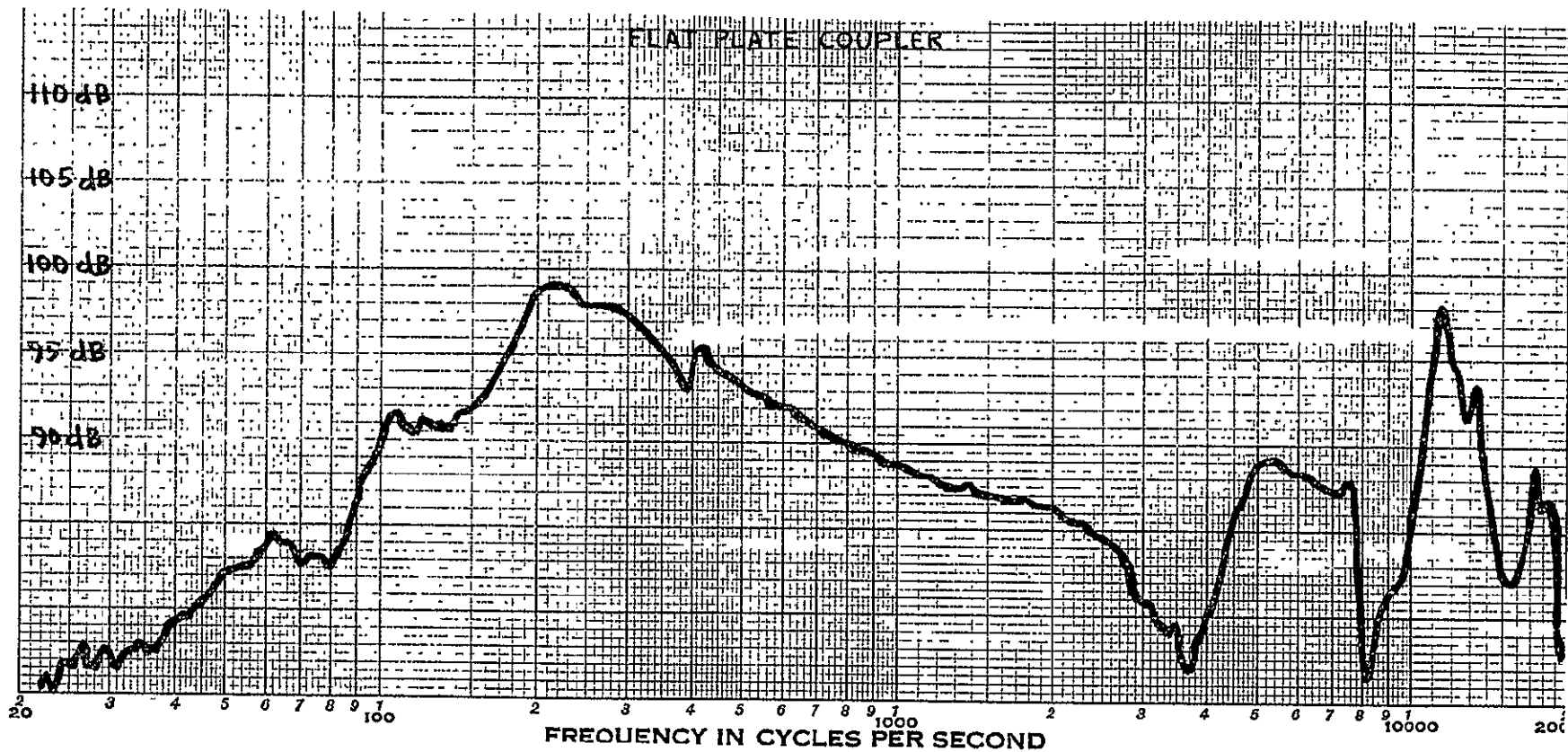


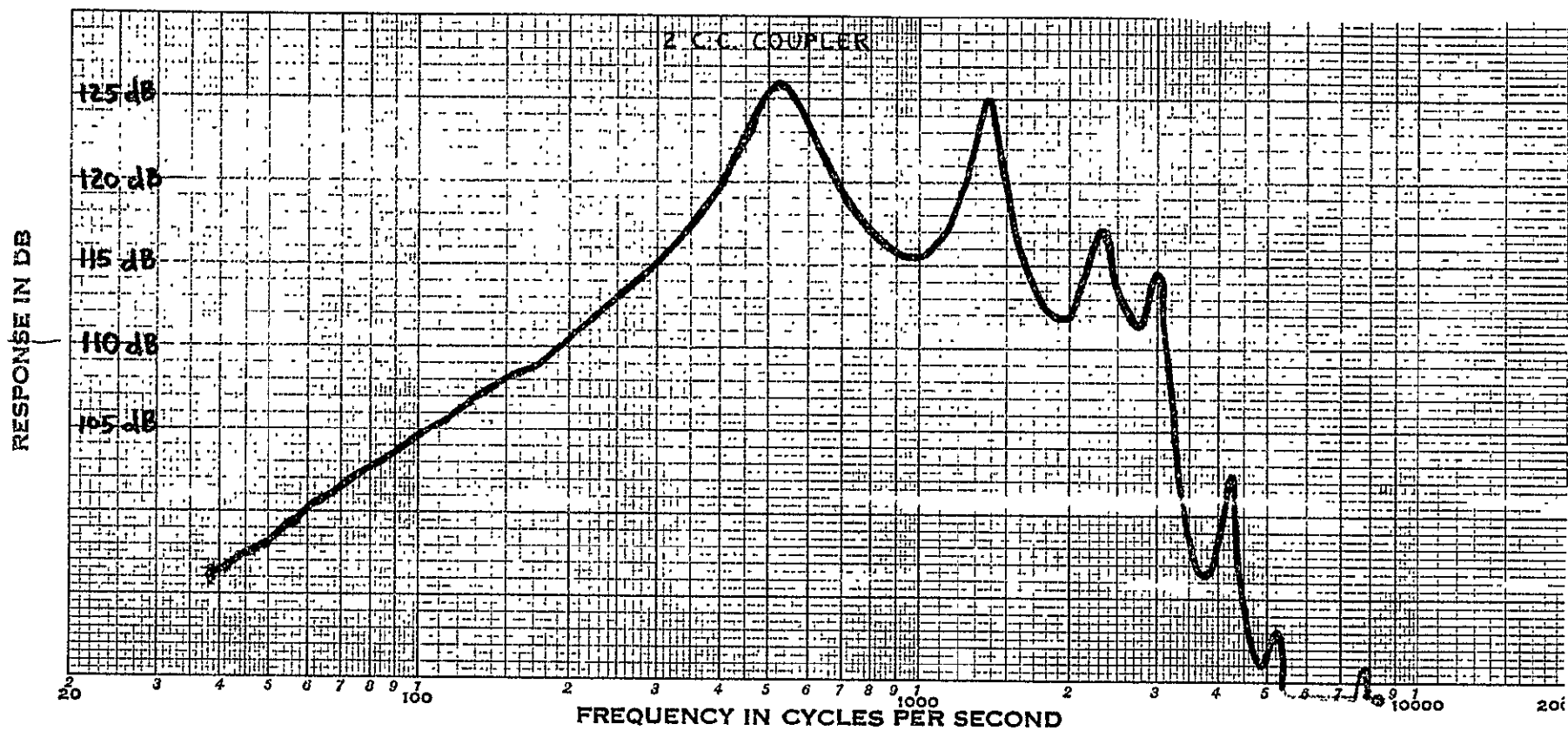
2b. 125610 EARPHONE (LEFT)



3a. HMD110 EARPHONE (LEFT)

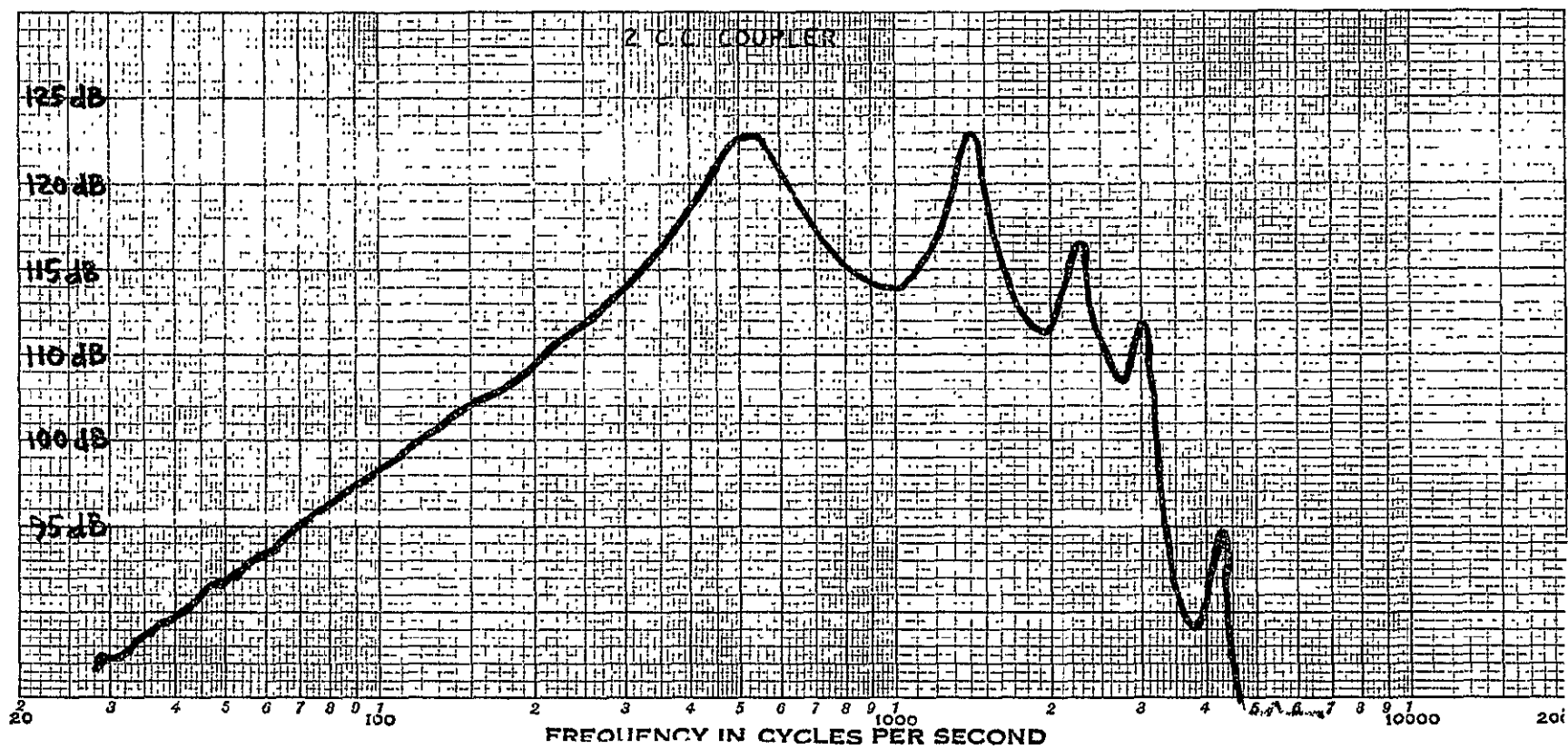
RESPONSE IN DB





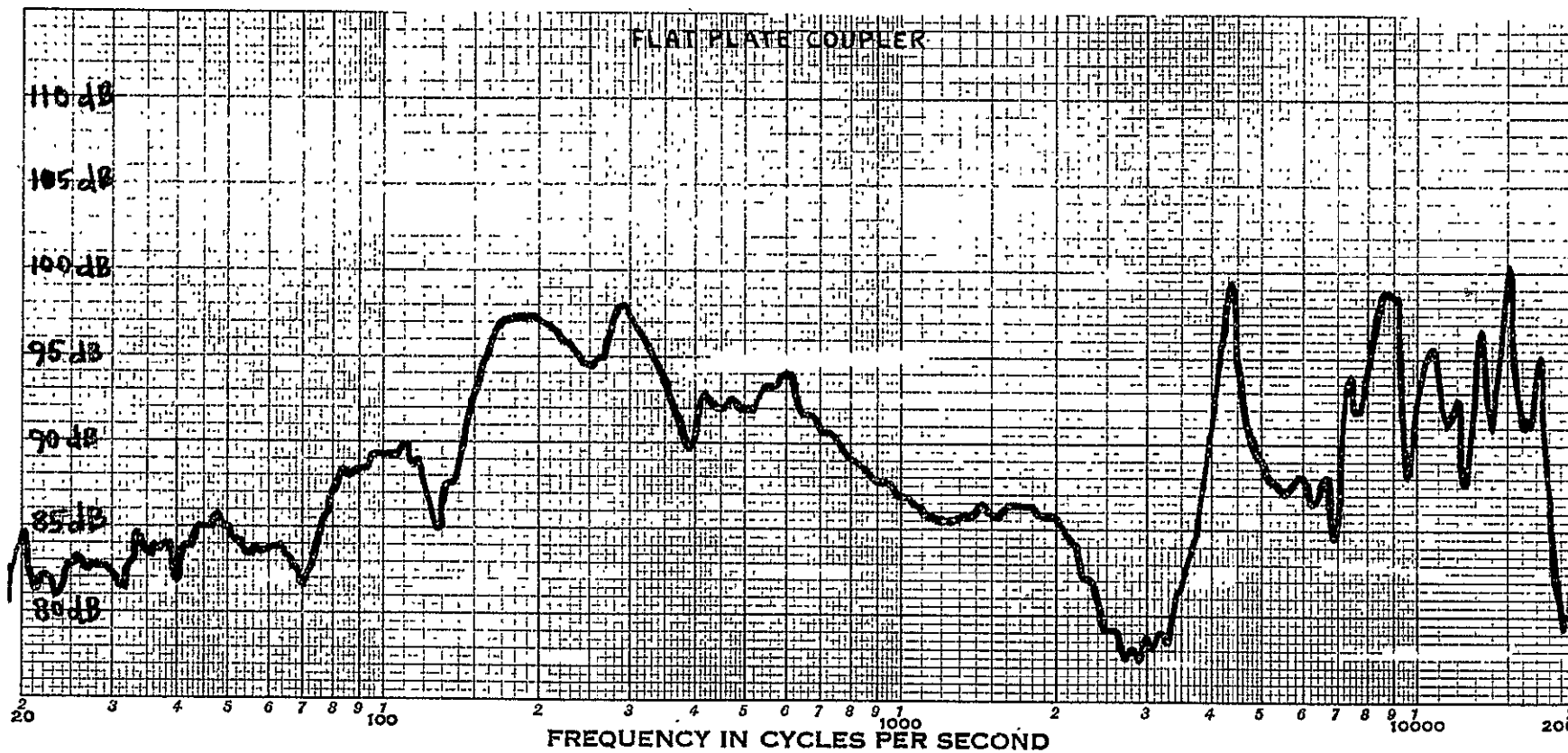
4a. 5x5 EARPHONE (LEFT)

RESPONSE IN DB

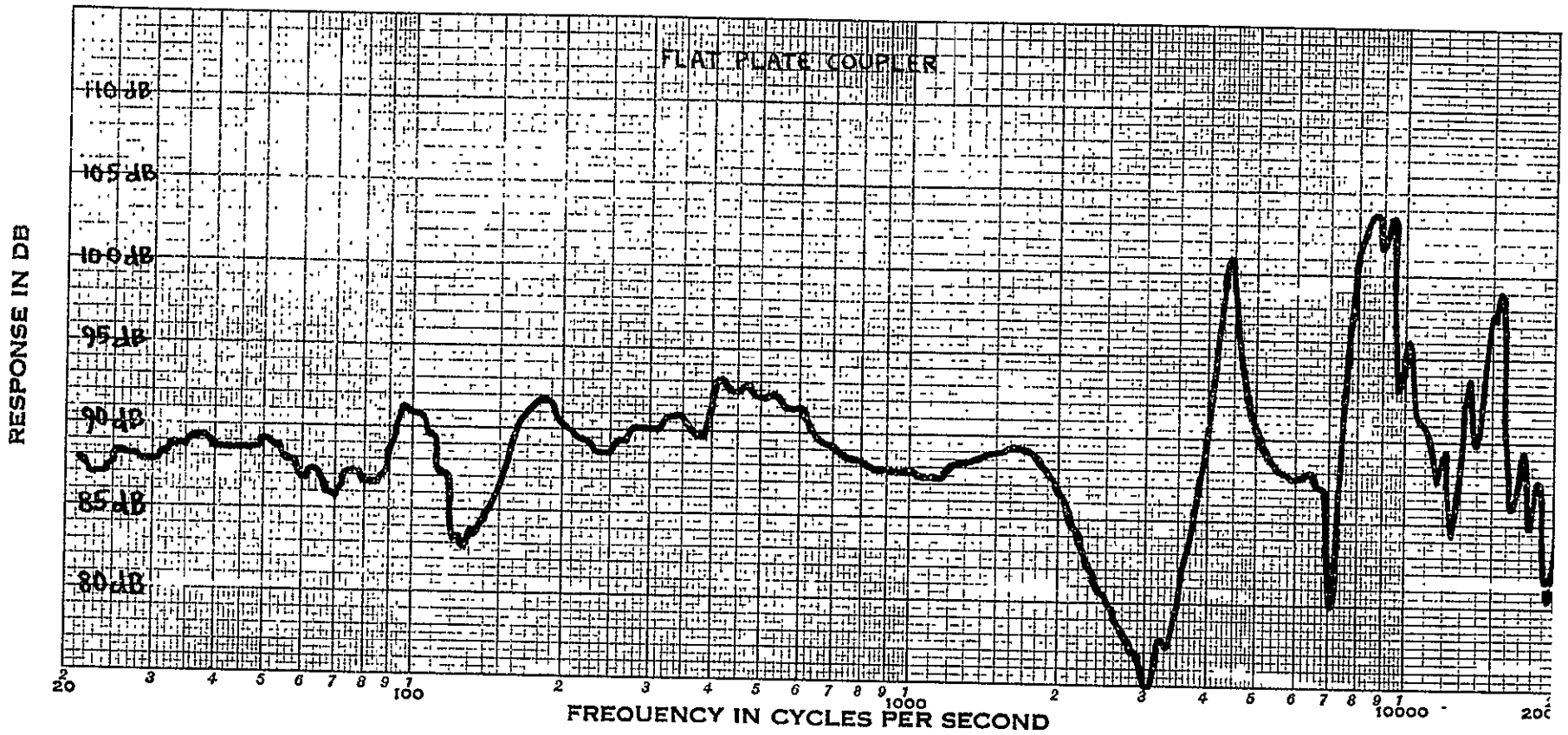


4b. RIGHT

RESPONSE IN DB

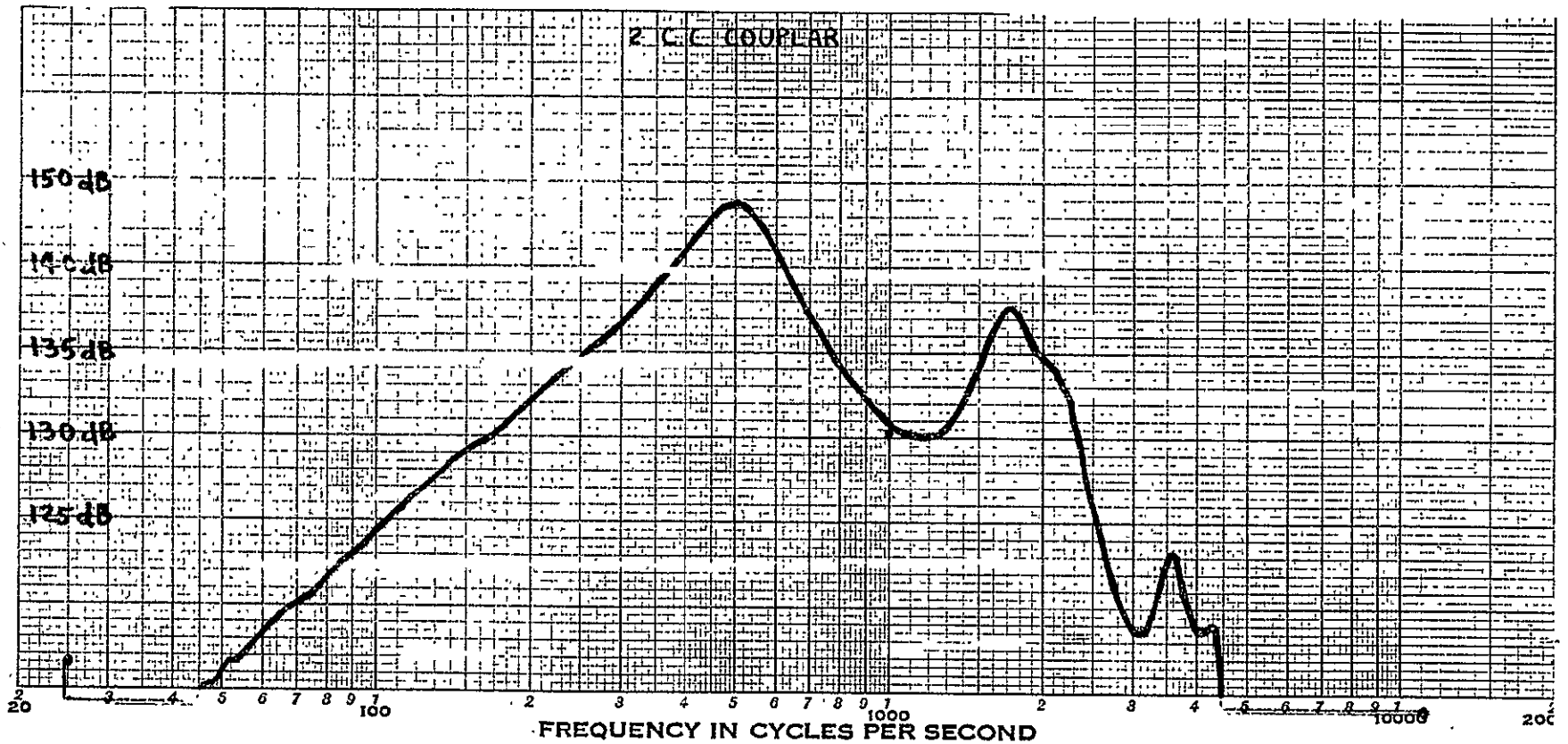


5a. LT-730 EARPHONE (LEFT)

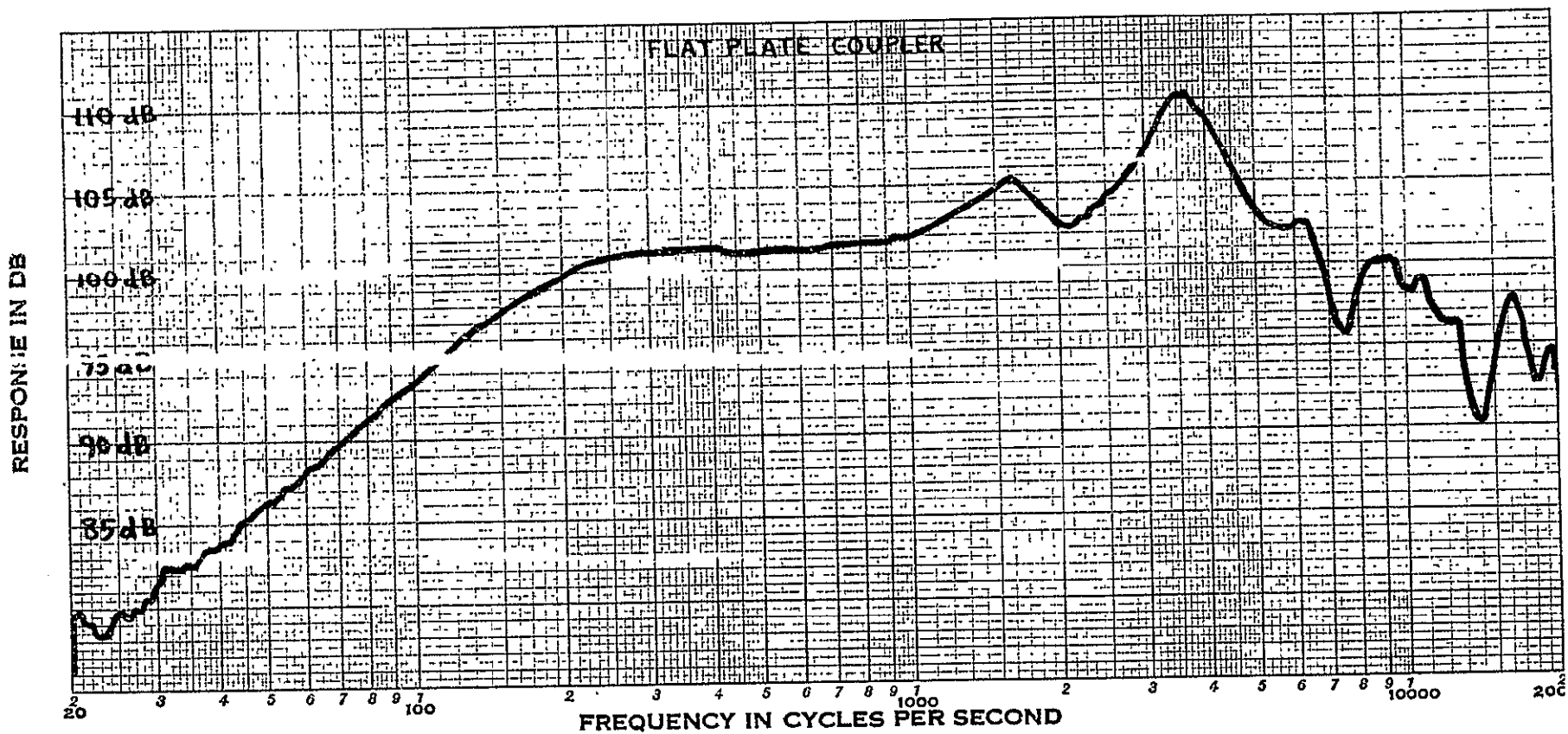


5b. RIGHT

RESPONSE IN DB

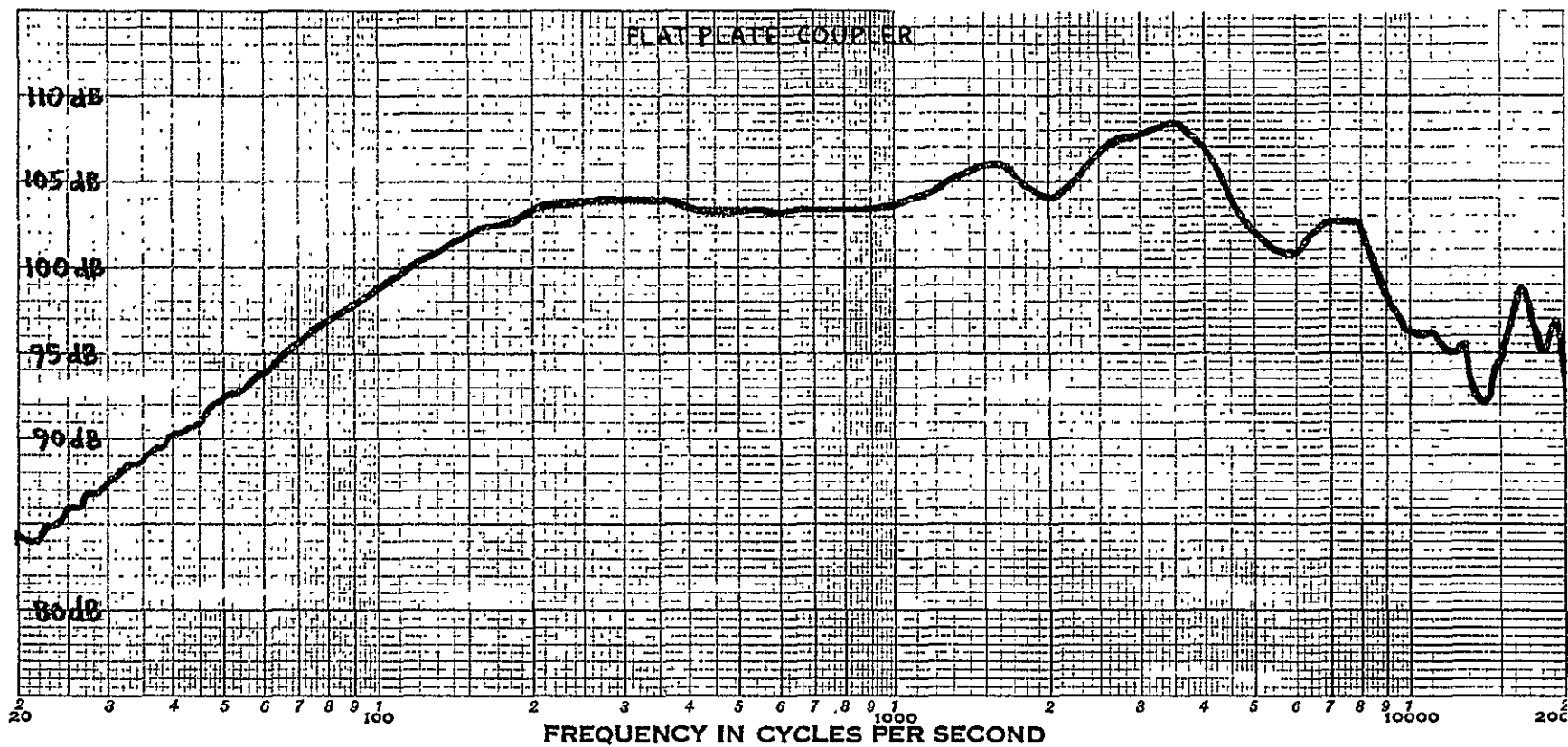


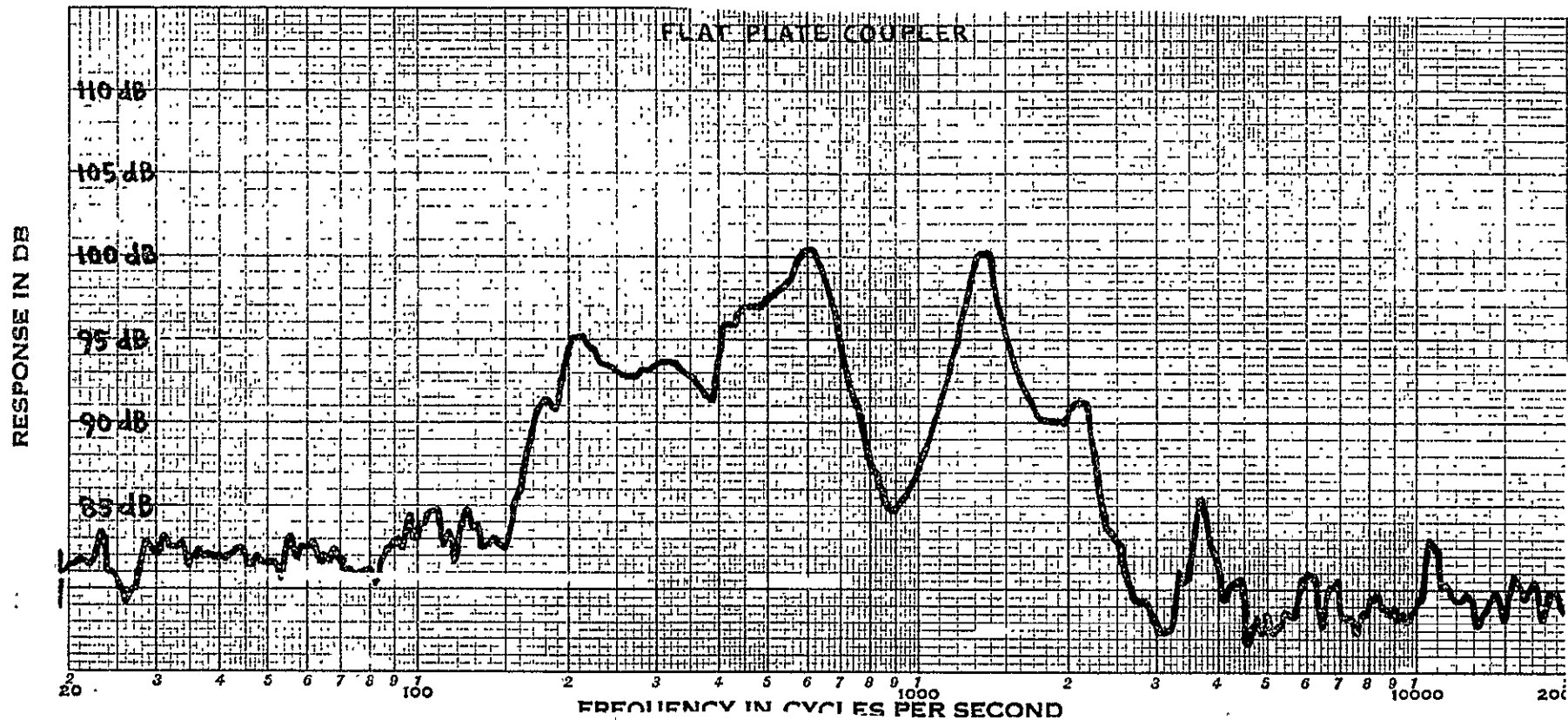
6. HS-2A EARPHONE (SINGLE EAR ONLY)



7a. HMD414 EARPHONE (LEFT)

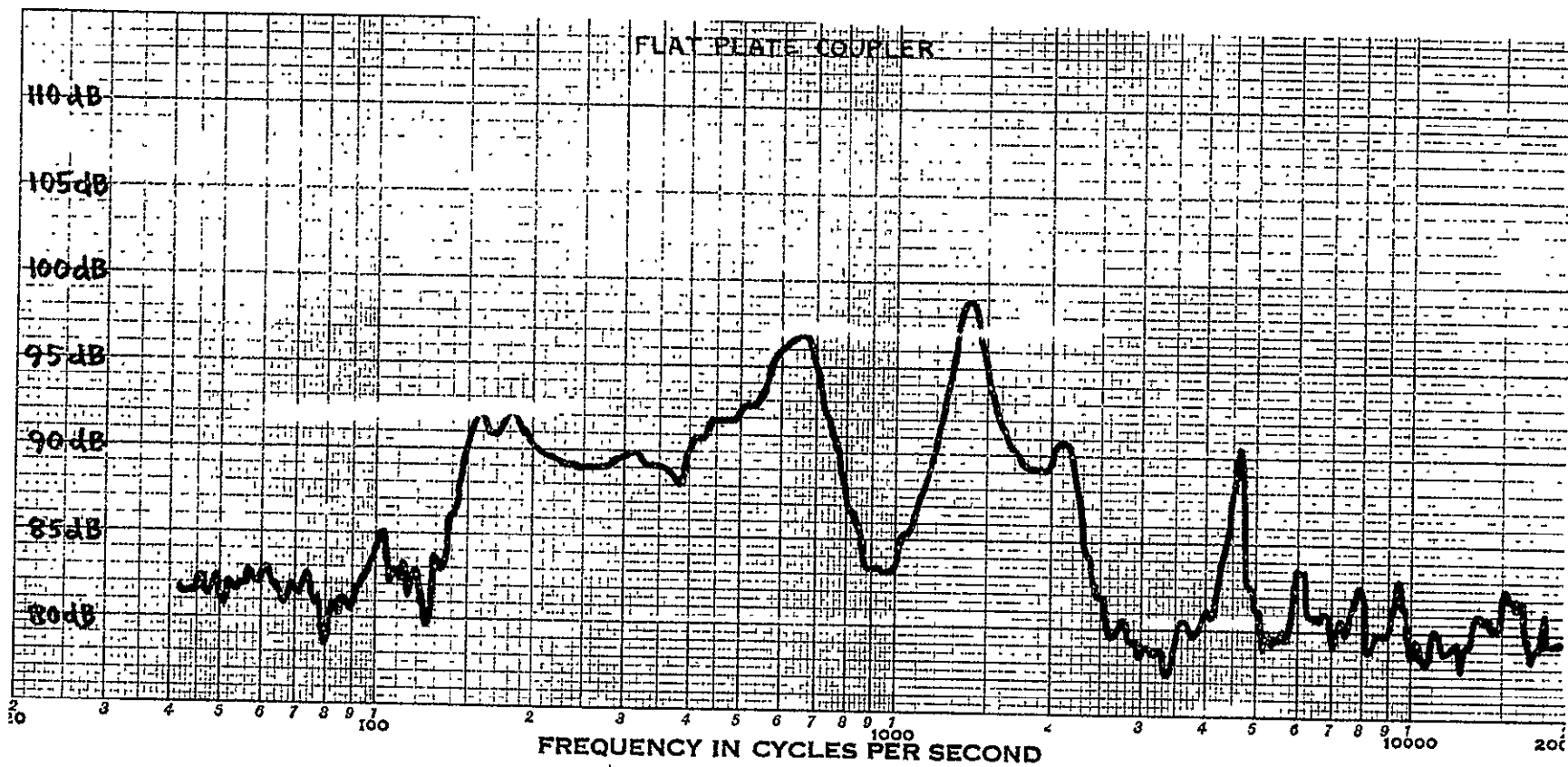
RESPONSE IN DB





8a. A610 EARPHONE (LEFT)

RESPONSE IN DB



8b. RIGHT

E. Impedance

<u>HEADSET</u>	<u>MICROPHONE (OHMS)</u>	<u>EARPHONE (SINGLE)</u>
1. HMD110	245	200
2. HMD414	235	2500
3. HS-2A	1000	740
4. 5x5	40 (from decoupling circuit)	980
5. A610	No Mic	270
6. TAH-29	No Mic	320
7. LTV-730	300	270
8. 125610	190	280

F. Headset Weight (Lightest to heaviest)

1. HS-2A	33 grams	±10%
2. 5x5	210 grams	
3. A610	240 grams	
4. HMD414	330 grams	
5. 125610	345 grams	
6. TAH-29	360 grams	
7. LT-730	430 grams	
8. HMD110	436 grams	

G. Distortion

The microphones and earphones measured less than .5% distortion at the 100 dB SPL level. Since the noise figure of the B&K microphone is 46 dB SPL equivalent, the lowest distortion measurement possible is .2% for the earphones. The Artificial voice of B&K is rated at "less than 1%". It was determined that the distortion levels of all microphones and earphones were satisfactory. More stringent measurements were deemed beyond the scope of this report.

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I. Wearer Comfort

The subjective comments concerning wearer comfort were taken after the headset had been worn in the test for intelligibility.

	<u>SUBJECT</u>					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	AVG
TAH-29	G	F	G	F	G	G-
HMD110	P	G	F	F	F	F
HMD414	P	G	G	P	F	F
LTV-730	G	G	G	G	G	G
125610	F	G	G	F	F	F+
A610	F	G	F	F	F	F
HS-2A	P	G	G	F	F	F+
5x5	P	P	P	P	P	P

P = POOR

F = FAIR

G = GOOD

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APPENDICES

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Telephonics

770 PARK AVENUE, HUNTINGTON, NEW YORK 11743
(516) 549-6000 / TWX: 510-226-6983 / Cable: INSSYSTHTGN

March 2, 1976

Gentlemen:

Telephonics has recently been awarded a Government contract to develop and manufacture a state-of-the-art audio communication system for the Space Shuttle program.

One aspect of this effort will be to evaluate a light weight headset (consisting of noise cancelling microphone and earphones) currently available for parameters which will include intelligibility, frequency response, sensitivity, distortion, noise isolation, acoustic quality, reliability, weight, wearer comfort, maintainability, and environmental stamina.

The test conditions have not been formally defined at this time, however, all headsets will be tested under identical conditions using ANSI or military test procedures. It is noted that Telephonics does not have a headset which will be part of this evaluation program.

If you feel that you have a headset(s) suitable for the Space Shuttle program, we would appreciate receiving a technical description, together with price and delivery quotation for an evaluation unit at your earliest convenience.

Sincerely,

TELEPHONICS, A Division of
Instrument Systems Corporation

Ed Joscelyn
Audio Products Engineering Manager

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APPENDIX B

LIST OF MANUFACTURERS SOLICITED

Adec Inc.
David Clark
Sennheiser
J. Ray Morris
Tibbetts Industries
Bolt Beranek & Newman
Dyna Magnetics Devices
Allen Tel Products
Altec Corp, Altec Div.
Applied Magnetics Corp.
Astatic Corp.
Astrocom Electronics Inc.
Audiosears Corp.
Avid Corp.
J.C. Carter Co.
Conrac Corp., Turner Div
Dobbs - Stanford Corp.
Dukano Corp.
Electro Vox Industries
Gulton/Electrovoice Inc.
Knowles Electronics
Koss Corp.
Lear Siegler Inc.
Matsushita, Panasonic
Mura Corp.
Murdock Corp.
Philmore Mfg. Co.
Plantronics Co.
Roanwell Corp.
Rye Industries
Scintrex Inc.
Telex Communications Co.

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APPENDIX C

May 24, 1976

TELEPHONICS SCREENING AUDIOMETER

THD-39 with MX41/AR

SPL FOR 60 DB HTL

<u>FREQ.</u>	<u>NORMAL CAL LEVEL</u> (ANSI 1969)	<u>MEASURED</u> RED	<u>LEVEL</u> BLUE
250 HZ	85.5	87.0	83.5
500 HZ	71.5	70.0	69.5
1000	67.0	66.5	66.5
2000	69.0	68.0	67.0
3000	70.0	70.0	69.0
4000	69.5	69.5	68.5
6000	75.5	75.0	77.5

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Hz	DECIBEL LOSS	
	RIGHT	LEFT
250	20	15
500	25	20
1000	15	15
1500		
2000	5	0
3000	0	0
4000	0	0
6000	10	5
8000		

AUDIOGRAM RESULTS

- ☐ Hearing Normal
☐ Advised to Consult Ear Doctor

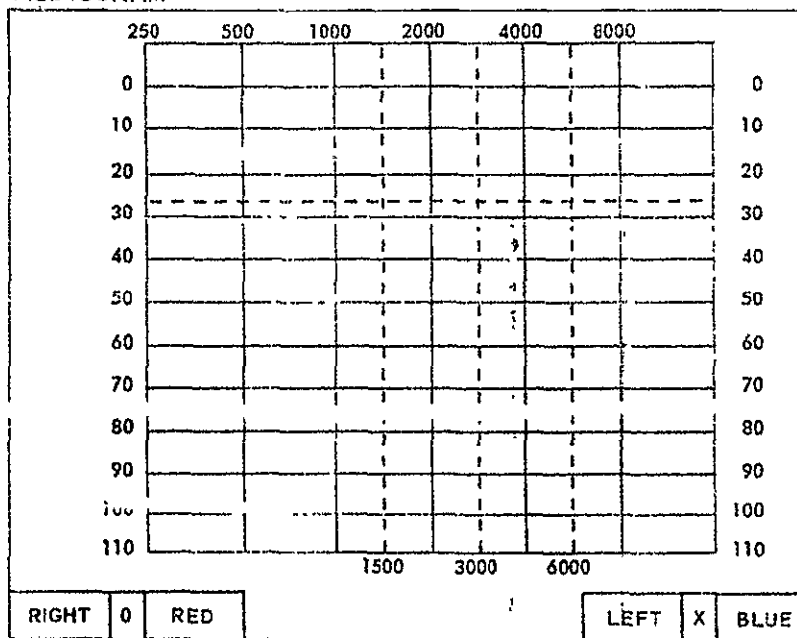
Class of Impairment _____

CHECK ONE: ☐ ANSI
☐ ISO
☐ ASA

PRINTED IN U.S.A.

AUDIOGRAM JOE "C"

Hearing Threshold Level in Decibels



Technician _____
Station _____ Audiometer Serial No. _____
Date _____ Time _____

EMPLOYERS INSURANCE OF WAUSAU

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OF POOR QUALITY

2

Hz	DECIBEL LOSS	
	RIGHT	LEFT
250	15	20
500	10	10
1000	10	10
1500		
2000	0	5
3000	0	0
4000	0	10
6000	0	5
8000		

AUDIOGRAM RESULTS

- ☐ Hearing Normal
☐ Advised to Consult Ear Doctor

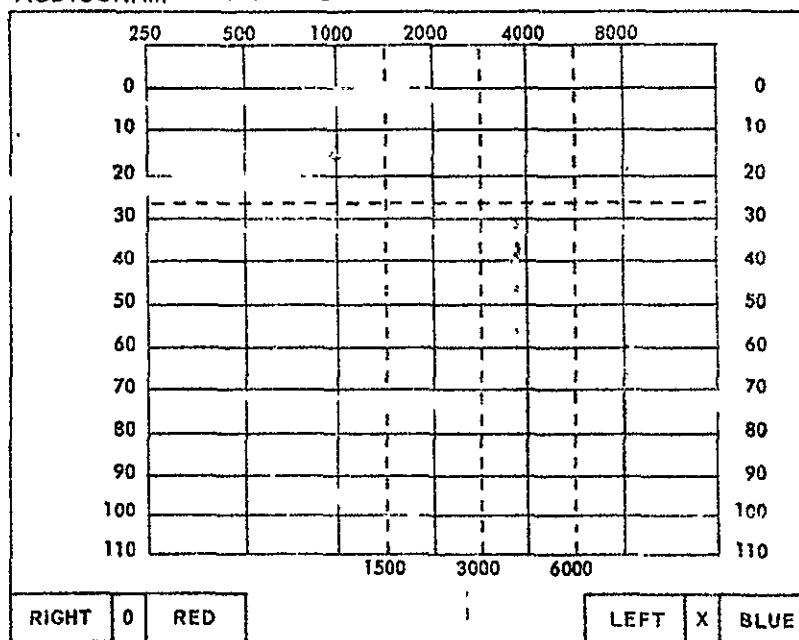
Class of Impairment _____

CHECK ONE: ☐ ANSI
☐ ISO
☐ ASA

10-1020-1A 1-78
 PRINTED IN U.S.A.

AUDIOGRAM JUNE "0"

Hearing Threshold Level in Decibels



Technician _____
 Station _____
 Date _____

Audiometer
 Serial No. _____
 Time _____

EMPLOYERS INSURANCE OF WAUSAU

ORIGINAL PAGE IS
OF POOR QUALITY

Hz	DECIBEL LOSS	
	RIGHT	LEFT
250	20	15
500	15	5
1000	0	0
1500		
2000	0	0
3000	15	20
4000	10	15
6000	0	10
8000		

AUDIOGRAM RESULTS

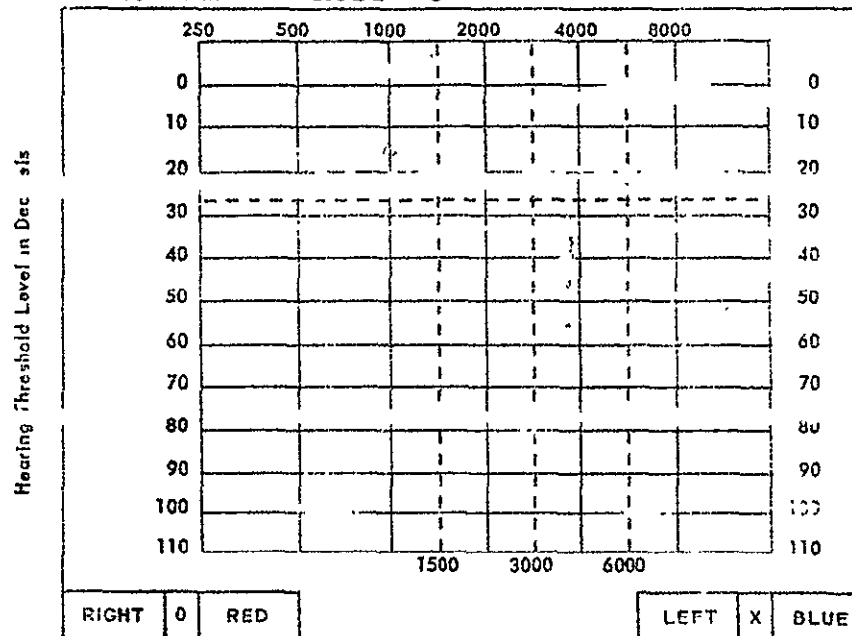
- ☐ Hearing Normal
☐ Advised to Consult Ear Doctor

Class of Impairment _____

CHECK ONE: ☐ ANSI
☐ ISO
☐ ASA

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AUDIOGRAM RUSS "G"



Technician _____

Station _____ Audiometer Serial No. _____

Date _____ Time _____

EMPLOYERS INSURANCE OF WAUSAU

ORIGINAL PAGE IS
OF POOR QUALITY

Hz	DECIBEL LOSS	
	RIGHT	LEFT
250	15	15
500	15	15
1000	0	0
1500		
2000	0	0
3000	15	20
4000	10	15
6000	0	10
8000		

AUDIOGRAM RESULTS

- ☐ Hearing Normal
☐ Advised to Consult Ear Doctor

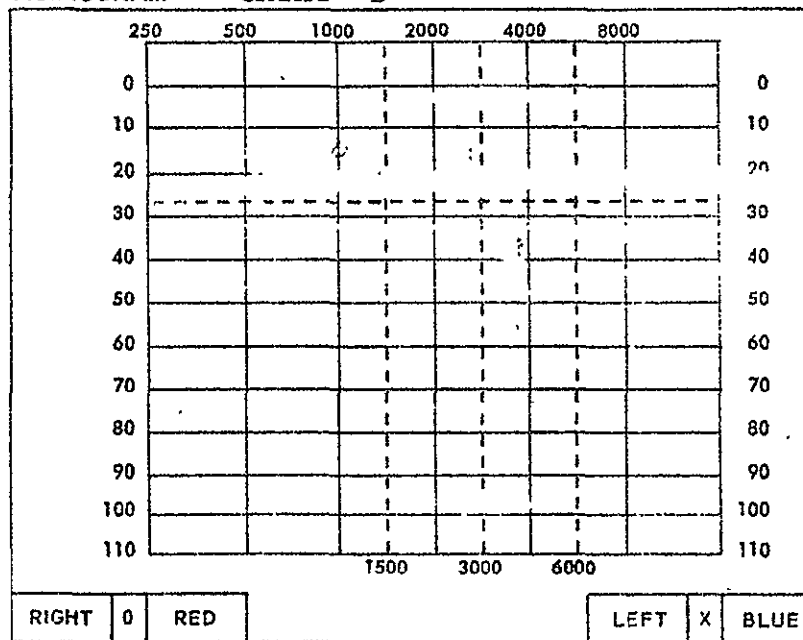
Class of Impairment _____

CHECK ONE: ☐ ANSI
☐ ISO
☐ ASA

104 1059 1A 171
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AUDIOGRAM CATHY "D"

Hearing Threshold Level in Decibels



Technician _____
 Station _____ Audiometer Serial No. _____
 Date _____ Time _____

EMPLOYERS INSURANCE OF WAUSAU

2

Hz	DECIBEL LOSS	
	RIGHT	LEFT
250	10	15
500	10	15
1000	5	10
1500		
2000	0	5
3000	0	5
4000	0	0
6000	0	20
8000		

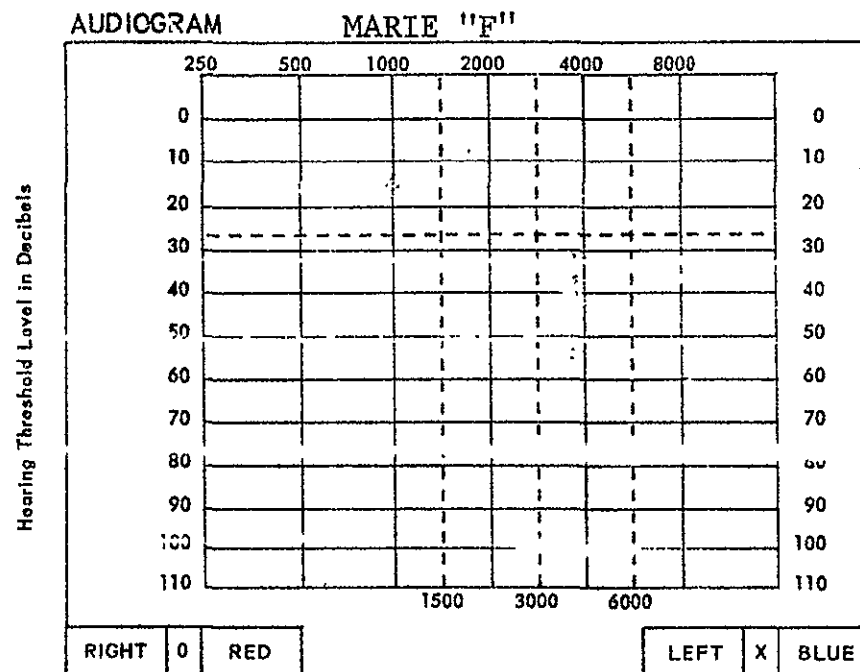
AUDIOGRAM RESULTS

- ☐ Hearing Normal
☐ Advised to Consult Ear Doctor

Class of Impairment _____

CHECK ONE: ☐ ANSI
☐ ISO
☐ ASA

304 1050-1A 1-73
 PRINTED IN U.S.A.

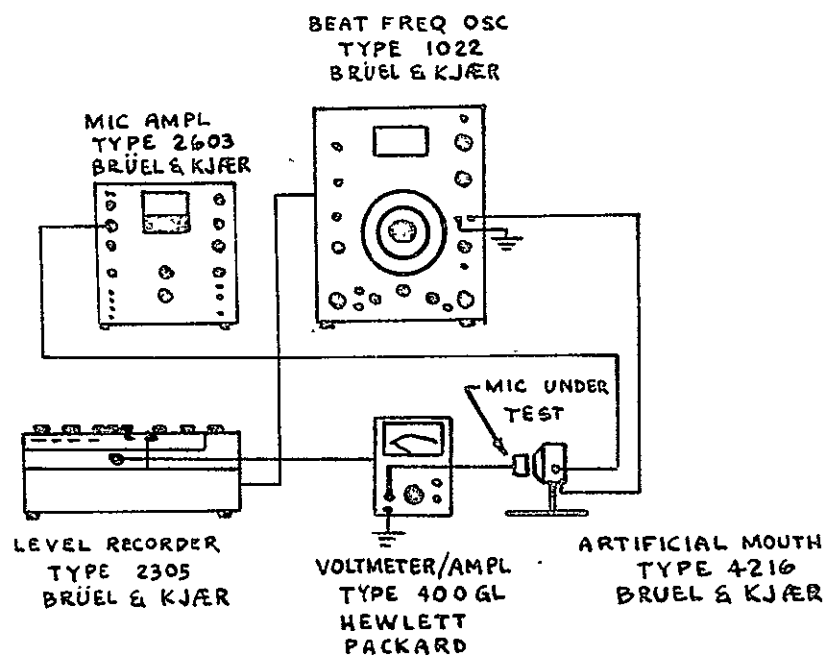


Technician _____

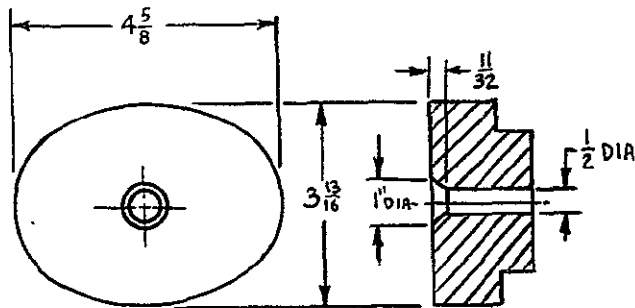
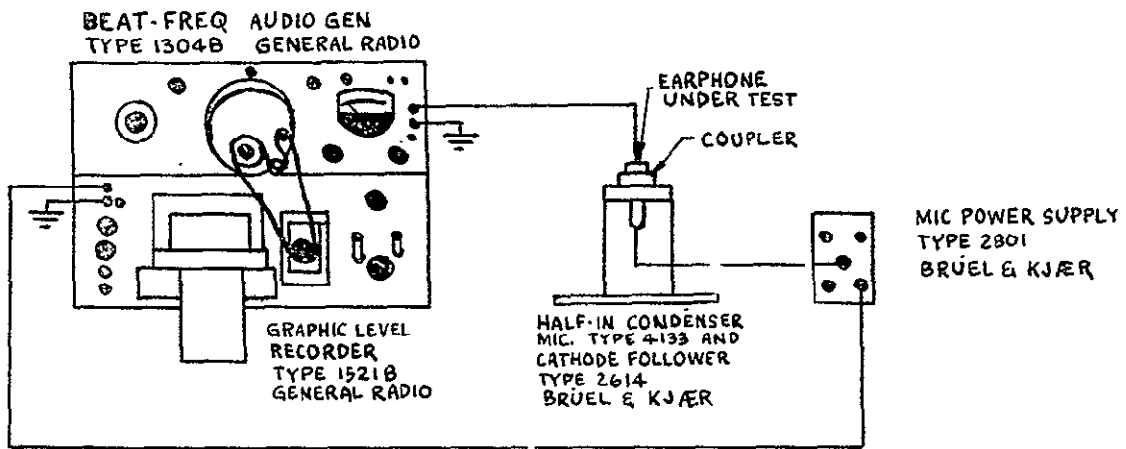
Station _____ Audiometer Serial No. _____

Date _____ Time _____

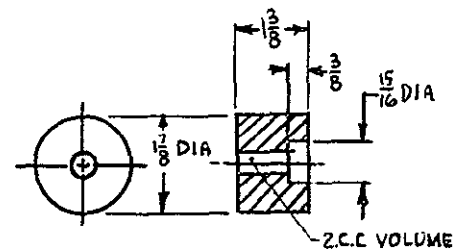
EMPLOYERS INSURANCE OF WAUSAU



MICROPHONE TEST APPARATUS



FLAT PLATE COUPLER



2 C.C. COUPLER

EARPHONE TEST APPARATUS

Telephonics

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HMD-110
MICROPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
98	-.4	.16
98	-.4	.16
100	1.6	2.56
96	-2.4	5.76
100	1.6	2.56
<u>492</u>		<u>11.2</u>

$$\begin{aligned}\bar{X} &= 98.4 \\ V &= 2.8 \\ \sigma &= 1.67\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
100	4.8	23.04
94	-1.2	1.44
94	-1.2	1.44
94	-1.2	1.44
94	-1.2	1.44
<u>476</u>		<u>28.8</u>

$$\begin{aligned}\bar{X} &= 95.2 \\ V &= 7.2 \\ \sigma &= 2.68\end{aligned}$$

Telephonics

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5x5
MICROPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
98	0	0
94	-4	16
98	0	0
100	2	4
100	2	4
<u>490</u>		<u>24</u>

$$\bar{X} = 98.0$$

$$V = 6$$

$$\sigma = 2.45$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
98	4	16
90	-4	16
92	-2	4
94	0	0
96	2	4
<u>470</u>		<u>40</u>

$$\bar{X} = 94.0$$

$$V = 10$$

$$\sigma = 3.16$$

Telephonics

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LT-730
MICROPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
98	-.8	.64
100	1.2	1.44
100	1.2	1.44
98	-.8	.64
98	-.8	.64
<u>494</u>		<u>4.8</u>

$$\begin{aligned}\bar{X} &= 98.8 \\ V &= 1.2 \\ \sigma &= 1.095\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
64	10.8	116.64
78	3.2	10.24
64	10.8	116.64
90	15.2	231.04
78	3.2	10.24
<u>374</u>		<u>484.8</u>

$$\begin{aligned}\bar{X} &= 74.8 \\ V &= 121.2 \\ \sigma &= 11.0\end{aligned}$$

Telephonics

A DIVISION OF INSTRUMENT SYSTEMS CORPORATION

HMD414
MICROPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
100	1.2	1.44
100	1.2	1.44
98	-.8	.16
100	1.2	1.44
96	-2.8	7.84
<u>494</u>		<u>12.34</u>

$$\begin{aligned}\bar{X} &= 98.8 \\ V &= 3.08 \\ \sigma &= 1.75\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
90	2.8	7.84
72	-15.2	231.04
98	10.8	116.64
84	- 3.2	10.24
92	4.8	23.04
<u>436</u>		<u>388.8</u>

$$\begin{aligned}\bar{X} &= 87.2 \\ V &= 97.2 \\ \sigma &= 9.85\end{aligned}$$

Telephonics

A DIVISION OF INSTRUMENT SYSTEMS CORPORATION

125610
MICROPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
96	-1.6	2.56
100	+2.4	5.76
96	-1.6	2.56
96	-1.6	2.56
100	+2.4	5.76
<u>488</u>		<u>19.2</u>

$$\begin{aligned}\bar{X} &= 97.6 \\ V &= 4.8 \\ \sigma &= 2.19\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
94	11.6	134.56
80	-2.4	5.76
56	26.4	696.96
86	3.6	12.96
96	13.6	184.96
<u>412</u>		<u>1035.2</u>

$$\begin{aligned}\bar{X} &= 82.4 \\ V &= 258.8 \\ \sigma &= 16\end{aligned}$$

Telephonics

A DIVISION OF INSTRUMENT SYSTEMS CORPORATION

HS-2A
MICROPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
98	3	9
92	-3	9
96	1	1
94	-1	1
95	0	0
<u>475</u>		<u>20</u>

$$\begin{aligned}\bar{X} &= 95.0 \\ V &= 5 \\ \sigma &= 2.33\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
80	-1	1
82	1	1
74	-7	49
86	5	25
83	2	4
<u>81</u>		<u>80</u>

$$\begin{aligned}\bar{X} &= 81 \\ V &= 20 \\ \sigma &= 4.47\end{aligned}$$

Telephonics

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TAH-29
EARPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
92	-4.8	23.04
96	- .8	.64
98	1.2	1.44
98	1.2	1.44
100	3.2	10.24
<u>484</u>		<u>36.8</u>

$$\begin{aligned}\bar{X} &= 97.8 \\ V &= 9.2 \\ \sigma &= 3.03\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
98	5.8	33.64
94	1.8	3.24
90	-2.2	4.84
90	-2.2	4.84
89	-3.2	10.24
<u>461</u>		<u>56.8</u>

$$\begin{aligned}\bar{X} &= 92.2 \\ V &= 14.2 \\ \sigma &= 3.76\end{aligned}$$

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HMD414
EARPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
96	1.6	2.56
94	-3.6	12.96
100	2.4	5.76
100	2.4	5.76
98	.4	.16
<u>488</u>		<u>27.2</u>

$$\begin{aligned}\bar{X} &= 97.6 \\ V &= 6.8 \\ \sigma &= 2.6\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
50	5.2	27.04
40	-4.8	23.04
30	-14.8	219.04
64	19.2	368.64
40	-4.8	23.04
<u>224</u>		<u>660.8</u>

$$\begin{aligned}\bar{X} &= 44.8 \\ V &= 165.2 \\ \sigma &= 12.85\end{aligned}$$

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5x5
EARPHONE

QUIET

<u>X</u>	<u>X-$\bar{X}$</u>	<u>(X-$\bar{X}$)²</u>
98	2.4	5.76
98	-7.6	57.76
96	.4	.16
96	.4	.16
100	4.4	19.36
<u>478</u>		<u>83.2</u>

$$\begin{aligned}\bar{X} &= 95.6 \\ V &= 20.8 \\ \sigma &= 4.56\end{aligned}$$

NOISE

<u>X</u>	<u>X-$\bar{X}$</u>	<u>(X-$\bar{X}$)²</u>
74	+14	196
40	-20	400
54	- 6	36
42	-18	324
90	30	900
<u>300</u>		<u>1856</u>

$$\begin{aligned}\bar{X} &= 60 \\ V &= 464 \\ \sigma &= 21.5\end{aligned}$$

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UNEX HS-2A
EARPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
94	-12	1.44
90	- 5.2	27.04
96	.8	.64
100	4.8	23.04
96	18	.64
<u>476</u>		<u>52.8</u>

$$\begin{aligned}\bar{X} &= 95.2 \\ V &= 13.2 \\ \sigma &= 3.63\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
48	-2	4
46	-4	16
66	16	256
36	-14	196
54	4	16
<u>250</u>		<u>488</u>

$$\begin{aligned}\bar{X} &= 50 \\ V &= 122 \\ \sigma &= 11.0\end{aligned}$$

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125610
EARPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
98	+2	4
92	-4	16
96	0	0
98	2	4
<u>384</u>		<u>24</u>

$$\begin{aligned}\bar{X} &= 96 \\ V &= 8 \\ \sigma &= 2.83\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
88	-11.5	132.25
82	5.5	30.25
94	17.5	306.25
42	-34.5	1190.25
<u>306</u>		<u>1659.</u>

$$\begin{aligned}\bar{X} &= 76.5 \\ V &= 553 \\ \sigma &= 23.52\end{aligned}$$

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HMD110
EARPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
96	-2	4
94	0	0
100	6	36
98	4	16
82	-12	144
<u>470</u>		<u>200</u>

$$V_{or} = \frac{200}{4} \quad \begin{array}{l} \bar{X} = 94 \\ = 50 \\ \sigma = 7.07 \end{array}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
84	13.6	184.96
66	4.4	19.36
84	13.6	184.96
78	7.6	57.76
40	-30.4	924.16
<u>352</u>		<u>1371.2</u>

$$\begin{array}{l} \bar{X} = 70.4 \\ V = 342.8 \\ \sigma = 18.5 \end{array}$$

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A610
EARPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
92	0	0
88	-4	16
90	-2	4
96	4	16
94	2	4
<u>460</u>		<u>40</u>

$$\begin{aligned}\bar{X} &= 92 \\ V &= 10 \\ \sigma &= 3.16\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
30	14.4	207.36
20	4.4	19.36
10	- 5.6	31.86
8	- 7.6	57.76
10	- 5.6	31.36
<u>78</u>		<u>34.72</u>

$$\begin{aligned}\bar{X} &= 15.6 \\ V &= 86.8 \\ \sigma &= 9.32\end{aligned}$$

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LT-730
EARPHONE

QUIET

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
96	-.5	.25
96	-.5	.25
96	-.5	.25
98	1.5	2.25
-	-	-
<u>386</u>		<u>3</u>

$$\begin{aligned}\bar{X} &= 96.5 \\ V &= 1 \\ \sigma &= 1\end{aligned}$$

NOISE

<u>X</u>	<u>X - $\bar{X}$</u>	<u>(X - $\bar{X}$)²</u>
50	-1	1
48	-3	9
84	33	1089
22	29	841
-	-	-
<u>204</u>		<u>1940</u>

$$\begin{aligned}\bar{X} &= 51 \\ V &= 646.6 \\ \sigma &= 25.42\end{aligned}$$

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Statistical Significance

The statistical significance of the intelligibility data is calculated below. The χ^2 distribution test was used. The results of the test illustrates that the rank ordering in many cases is justified. The large variance between subjects, however, in other cases showed the data not sampled sufficiently to achieve statistical significance. Samples from perhaps 20-30 tests would be necessary to accomplish this end.

The following example illustrates the calculation techniques used.

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Comparison of HMD414 and A610 earphone under no noise conditions.

$$\bar{X}_{414} = 97.6$$

$$\bar{X}_{610} = 92$$

Pick 90 as arbitrary origin

Let $\xi = X - 90$ and $C = \bar{X} - 90$

ξ 414	ξ^2 414	ξ 610	ξ^2 610
6	36	2	4
4	16	-2	4
10	100	0	0
10	100	6	36
8	64	4	16
<u>316</u>	<u>316</u>		<u>60</u>

$C_{414} = 97.6 - 90$ $C_{610} = 92 - 90$

$$s_{414}^2 = \frac{\sum \xi_{414}^2 - N_{414} C_{414}^2}{N_{414} - 1} = \frac{316 - 5(57.76)}{4} = 6.8$$

$$s_{610}^2 = \frac{\sum \xi_{610}^2 - N_{610} C_{610}^2}{N_{610} - 1} = \frac{60 - 5(4)}{4} = 10.0$$

$$s_{\bar{X}_{414}}^2 = \frac{6.8}{5} = 1.36$$

$$s_{\bar{X}_{610}}^2 = \frac{10}{5} = 2.00$$

$$\chi_{0.025}^2 (n = 4) = 2.776$$

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$$\text{Critical value } t_{.025} = \pm \frac{1.36 (2.776) + 2.00 (2.776)}{1.36 + 2.00} = \pm 2.776$$

to test difference

$$\frac{\bar{X}_{414} - \bar{X}_{610}}{\sqrt{s_{\bar{X}_{414}}^2 + s_{\bar{X}_{610}}^2}} = \frac{97.6 - 92}{\sqrt{1.36 + 2}} = \frac{56}{1.833} = 3.055$$

This does not lie within critical values ± 2.776 and therefore the 414 can be considered statistically significantly better than the A610.

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TAH-29 Compared to 125610 Earphone in noise.

$$\bar{X}_{29} = 92.2$$

$$\text{Let } \xi = X - 90$$

$$\text{Let } C = \bar{X} - 90$$

$$\bar{X}_{125} = 76.5$$

$$N = 5$$

ξ	ξ^2	
<u>29</u>	<u>29</u>	
8	64	
4	16	
0	0	
0	0	
-1	1	
	<u>81</u>	

$$C_{29} = 92.2 - 90$$

$$N = 4$$

ξ	ξ^2
<u>125</u>	<u>125</u>
-2	4
-8	64
4	16
<u>-48</u>	<u>2304</u>
	<u>2378</u>

$$\frac{s_{29}^2}{N_{29} - 1} = \frac{\sum \xi_{29}^2}{N_{29} - 1} - N_{29} C_{29}^2 = \frac{81 - 5(2.2)^2}{4} = 14.2$$

$$s_{125}^2 = \frac{2378 - 4(-13.5)^2}{3} = 549.66$$

$$s_{\bar{X}_{29}}^2 = \frac{14.2}{5} = 2.84$$

$$s_{\bar{X}_{125}}^2 = \frac{549.66}{4} = 137.4$$

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$$t_{.025} = \pm \frac{2.84(2.776) + 137.4(3.182)}{2.84 \pm 137.4} = \frac{445.08}{140.24} = \pm 3.17$$

$$\frac{\bar{X} - \bar{X}}{\sqrt{s_{\bar{X}}^2 + s_{\bar{X}}^2}} = \frac{92.2 - 76.5}{\sqrt{2.84 + 137.4}} = 1.325$$

Not Statistically Sig

The statistical significance for noise is indicated in the matrix below:

Headset In
Column below
is statistically
significant when
compared to headset in
Column to the right

	TAH29	125610	HMD110	5x5	LT-730	HS-2A	HMD414	A610
TAH-29	-			/*	/*	/*	/*	/*
125610		-						/*
HMD110			-		*/			/*
5x5				-	*/			/*
LT-730					-			/*
HS-2A						-		/*
HMD414					/		-	
A610								-

*Indicates Statistically Significant

Microphone/Headset

(Not all combination calculated)

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